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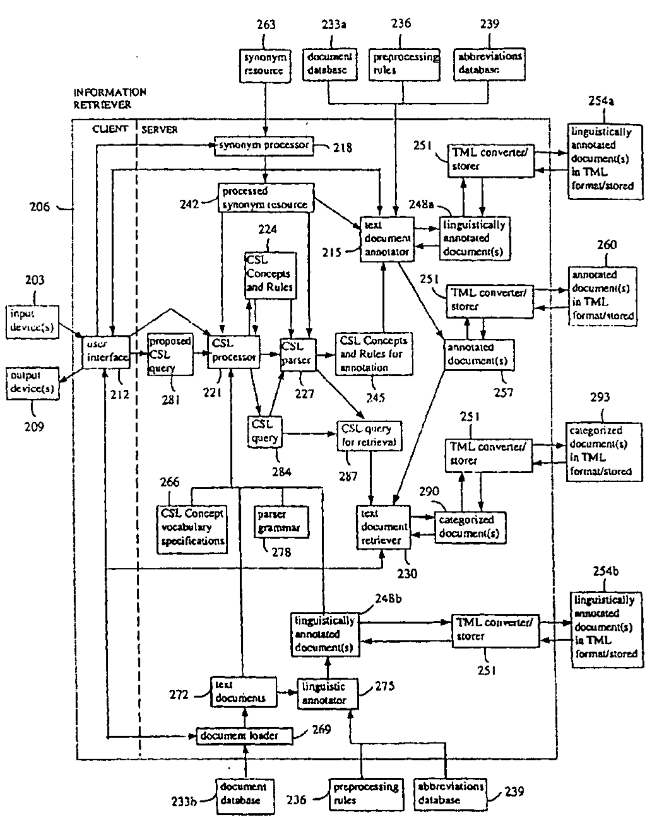
(54) **Title:** A METHOD AND SYSTEM FOR DESCRIBING AND IDENTIFYING CONCEPTS IN NATURAL LANGUAGE TEXT FOR INFORMATION RETRIEVAL AND PROCESSING



(57) Abstract: A method for information retrieval that matches occurrences of concepts in natural language text documents against descriptions of concepts in user queries. Said method, implemented in a computer system, includes a preferred version of the method that comprises (1) annotating natural language text in documents and other text-forms with linguistic information and Concepts and Concept Rules expressed in a Concept Specification Language (CSL) for a particular domain, (2) pruning and optimizing synonyms for a particular domain, (3) defining and learning said CSL Concepts and Concept Rules, (4) checking user-defined descriptions of Concepts represented in CSL (including user queries), and (5) retrieval by matching said user-defined descriptions (and queries) against said annotated text. CSL is a language for expressing linguistically-based patterns. Said patterns can represent the linguistic manifestations of concepts in text. Said concepts may derive from the sublanguages used by experts to analyze specialized domains including, but not limited to, insurance claims, police incident reports, medical reports, and aviation incident reports.

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A METHOD AND SYSTEM FOR DESCRIBING AND IDENTIFYING CONCEPTS IN NATURAL LANGUAGE TEXT FOR INFORMATION RETRIEVAL AND PROCESSING

Cross-reference to Related Application

This application claims the benefit of priority from United States provisional application no. 60/236,342 filed 09/29/2000.

TECHNICAL FIELD

The present invention relates most directly to the field of information retrieval, but also to the fields of query languages and query specification, text processing and linguistic annotation, and machine learning/knowledge acquisition.

BACKGROUND OF THE INVENTION

1. Information Retrieval

Information retrieval (IR) refers to "the retrieval of documents ... from large but specialized bodies of material, through the specification of document content rather than via keys like author names" (Sparck Jones, K., "Information Retrieval," In S. C. Shapiro (Ed.) *Encyclopedia of Artificial Intelligence, 2nd Edition*. John Wiley & Sons, New York, NY, pp. 1605-1613 (1992). In this invention the focus is on text retrieval (as opposed to audio or video retrieval). The problem of text retrieval has two parts: query specification, and retrieval of text documents.

Most IR systems use statistical techniques, depending on probabilistic models of query term distribution. For example, the Vector-Space approach is based on word occurrences (Salton, G., *The Smart Retrieval System - Experiments in Automatic Document Processing*, Prentice Hall, Englewood Cliffs, NJ (1971). Documents and queries are represented in a multi-dimensional space where each dimension corresponds to a word in the document collection. Relevant documents are those whose vectors are closest to the query vector.

In contrast to the Vector-Space focus on word occurrence distribution, approaches like Latent Semantic Indexing (Deerwester, S., Dumais, S., Furnas, G., Landauer, T., and R. Harshman, "Indexing by Latent Semantic Analysis," *Journal of the American Society for Information Science*, 41, pp. 391-407 (1990) are concerned with word co-occurrences. In this approach, the fact that two or more terms occur in the same document more often than chance is exploited to reduce the dimensionality of document and query space. Recent variants of these two basic approaches are described in Robertson, S. E., and S. Walker, "Okapi/Keenbow at TREC-8," In E. M. Vorhees and D. K. Harman (Eds.), Proceedings of the Eighth Text Retrieval Conference (TREC-8), Gaithersburg, MD: Department of Commerce, National Institute of Standards and Technology, NIST Special Publication 500-246, pp. 151-162 (1999); and Kwok, K., and M. Chan, "Improving Two-Stage Ad Hoc Retrieval for Short Queries," In Proceedings of SIGIR '98, pp. 250-256 (1998).

In contrast to these statistical approaches, there has been limited work that focusses on a rule-based or linguistic approach to IR. When used, such approaches are often combined with a statistical approach (Strzalkowski, T., Perez-Carballo, J., Karlgren, J., Hulth, A., Tapanainen, P., and T. Lahtinen, "Natural Language Information Retrieval: TREC-8 report," In Proceedings of the Eighth Text Retrieval Conference (1999).

The present invention differs from the current state of the art in two key respects: it allows users to specify richer queries using a query specification language and it offers a richer annotation of documents that might be potentially retrieved. On top of these improvements is more sophisticated matching of the richer user queries against the more richly annotated documents. Unlike the statistical approaches, the present invention does not rely on the results of ranking to determine whether a document should be returned to the user. Instead, it matches documents

against the concepts specified by the user. Ranking can be additionally used to prioritize documents, but it is not mandatory.

The present invention also differs from previous research because it does not only judge whether a document is relevant or not to a given query, it also identifies the specific portions of text that match the concept expressed by the input query. Therefore the present invention is not only relevant to IR purposes, but also to other fields like summarization and text mining.

Many patents describe methods and systems for information retrieval. Two of the most comprehensive recent IR patents are by Liddy et al. US patent no. 5963940 and US patent no. 6026388, but these differ markedly from the present invention. In particular, they do not provide its rich forms of annotation.

2. Query Languages and Query Specification

Query languages are traditionally associated with databases, i.e., repositories of structured data. Attempts have been made to extend database techniques and query languages to semi-structured data, particularly with the advent of the Worldwide Web (see, e.g., Buneman, P., "Semistructured Data." In Proceedings of the ACM Symposium on Principles of Database Systems, Tucson, AZ. Invited tutorial (1997)). An attempt at creating a query language for the XML markup language can be found in Deutsch, A., Fernandez, M., Florescu, D., Levy, A., and D. Suciu, "XML-QL: A Query Language for XML." Submission to the World Wide Web Consortium 19 August 1998 (Aug. 1998).

The limitations of the current approaches to querying unstructured data are pointed out in Lacroix, Z., Sahaguet, A., Chandrasekar, R., and B. Srinivas, "A Novel Approach to Querying the Web: Integrating Retrieval and Browsing." In ER97 Workshop on Conceptual Modeling for Multimedia Information Seeking, Los Angeles,

California, USA (Nov. 1997).. Most notably, the present invention suggests integrating query languages with some sort of text processing and IR techniques.

In a typical IR session, users specify their information needs by using key words, or by typing their requests using a natural language such as English (Manning, C., and H. Schutze, *Foundations of Statistical Natural Language Processing*, MIT Press, Cambridge, MA (1999)). Query languages in IR have been mostly confined to simple approaches like the bag-of-words approach. The IR system then converts these query words into a format relevant for the particular IR engine.

The present invention differs from these approaches in that it uses a specification language for the user to specify a query. The specification language allows the user to specify lexical, syntactic or semantic relationships. Using the specification language, the user specifies concepts that are required in the document, rather than just key words or entire natural language sentences. Concepts specified in this way are more accurate than simple keywords, and more general and flexible than complete sentences.

3. Text Processing and Linguistic Annotation

Linguistic annotation schemas exist for various kinds of linguistic information: phonetics, morphology, syntax, semantics, and discourse. See Bird, S., and M. Lieberman, "A Formal Framework for Linguistic Annotation." University of Pennsylvania, Dept. of Computer and Information Science, Technical Report MS-CIS-99-01 (1999) for a definition of 'linguistic annotation' and a review of the literature on linguistic annotation.

US patent no.5331556, Black et al. entitled "Method for natural language data processing using morphological and part-of-speech information" discloses in the abstract, "the method includes executing

linguistic analysis upon a text corpus file to derive morphological, part-of-speech information as well as lexical variants... to construct an enhanced text corpus file. A query text file is linguistically analyzed to construct a plurality of trigger token morphemes... used to construct a search mask stream... A match between the search mask stream and the enhanced corpus file allows a user to retrieve selected portions of the enhanced text corpus." However,US patent no.5331556 describes only a relatively general form of annotation, unlike the rich forms of annotation described in the present invention.

4. Machine Learning / Knowledge Acquisition

Machine learning (ML) refers to the automated acquisition of knowledge, especially domain-specific knowledge (cf.Schlimmer, J. C., and P. Langley, "Learning, Machine," In S. C. Shapiro (Ed.) *Encyclopedia of Artificial Intelligence, 2nd Edition*. John Wiley & Sons, New York, NY, pp. 785-805 (1992), p. 785). In the context of the present invention, ML concerns learning Concepts.

The system most closely related to the present task is Riloff's (1993) AutoSlog, a knowledge acquisition tool that uses a training corpus to generate proposed extraction patterns for the CIRCUS extraction system. See Riloff, E., "Automatically Constructing a Dictionary for Information Extraction Tasks," In Proceedings of the Eleventh National Conference on Artificial Intelligence (AAAI-93), pp. 811-816 (1993). A user either verifies or rejects each proposed pattern.

J.-T. Kim and D. Moldovan's (1995) PALKA system is a ML system that learns extraction patterns from example texts. See Kim, J.-T., and D. I. Moldovan, "Acquisition of Linguistic Patterns for Knowledge-Based Information Extraction," *IEEE Transactions on Knowledge and Data Engineering*, 7 (5), pp. 713-724 (Oct. 1995). The patterns are built using a fixed set of linguistic rules and relationships. Kim and Moldovan do not

suggest how to learn syntactic relationships that can be used within extraction patterns learned from example texts.

In Transformation-Based Error-Driven Learning (See Brill, E., "A Corpus-Based Approach to Language Learning," PhD. Dissertation, Department of Computer and Information Science, University of Pennsylvania, Philadelphia, PA (1993)), the algorithm works by beginning in a naive state about the knowledge to be learned. For instance, in tagging, the initial state can be created by assigning each word its most likely tag, estimated by examining a tagged corpus, without regard to context. Then the results of tagging in the current state of knowledge are repeatedly compared to a manually tagged training corpus and a set of ordered transformations is learnt, which can be applied to reduce tagging errors. The learnt transformations are drawn from a pre-defined list of allowable transformation templates. The approach has been applied to a number of other NLP tasks, most notably parsing (See Brill, E., "Transformation-Based Error-Driven Parsing," In Proceedings of the Third International Workshop on Parsing Technologies. Tilburg, The Netherlands (1993)).

The Memory-Based Learning approach is "a classification based, supervised learning approach: a memory-based learning algorithm constructs a classifier for a task by storing a set of examples. Each example associates a feature vector (the problem description) with one of a finite number of classes (the solution). Given a new feature vector, the classifier extrapolates its class from those of the most similar feature vectors in memory" (See Daelemans, W., S. Buchholz, and J. Veenstra, "Memory-Based Shallow Parsing," In Proceedings of the Computational Natural Language Learning (CoNLL-99) Workshop, Bergen, Norway, 12 June 1999 (1999)).

Explanation-Based Learning is "a technique to formulate general concepts on the basis of a specific training example" (van Harmelen, F., and A. Bundy, "Explanation-Based Generalization = Partial

Evaluation (Research Note)," *Artificial Intelligence*, 36, pp. 401-412 (1988)). A single training example is analyzed in terms of knowledge about the domain and the goal concept under study. The explanation of why the training example is an instance of the goal concept is then used as the basis for formulating the general concept definition by generalizing this explanation.

Huffman, US patent no. 5796926 and 5841895 describe methods for automatic learning of syntactic/grammatical patterns for an information extraction system. The present invention also describes methods for automatically learning linguistic information (including syntactic/grammatical information), but not in ways described by Huffman.

BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate a preferred embodiment of the invention:

FIG. **1** is a hardware block diagram showing an apparatus according to the invention;

FIG. **2** is a block diagram of the information retriever module shown in FIG. **1**;

FIG. **3** is a block diagram of the text document annotator module shown in FIG. **2**;

FIG. **4** is a block diagram of the annotator module shown in FIG. **3**;

FIG. **5** is a block diagram of the linguistic annotator module shown in FIG. **4**;

FIG. **6** is a block diagram of the preprocessor module shown in FIG. **5**;

FIG. **7** is a block diagram of the tagger module shown in FIG. **5**;

FIG. **8** is a block diagram of the parser module shown in FIG. **5**;

FIG. **9** is a block diagram of the conceptual annotator module shown in FIG. **4**;

FIG. **10** is a block diagram of the Concept identifier module shown in FIG. **9**;

FIG. **11** is a simplified Text Tree for *the cat chased the dog*;

FIG. **12** is a simplified Concept Tree for the Concept Animal containing the Concept Rules *"the*[1] Precedes[1] *dog"* and *"the*[2] Precedes[2] *cat"*;

FIG. **13** is a block diagram of the finite state automata for the single-term Pattern *A*;

FIG. **14** is a block diagram of the finite state automata for *A* Precedes *B*;

FIG. **15** is a simplified Concept Tree for the Concept "VX Dominates *dog*";

FIG. **16** is a block diagram of the finite state automata for "VX Dominates *dog*";

FIG. **17** is a block diagram of the finite state automata for *A* OR *B*;

FIG. **18** is a block diagram of the finite state automata for Concept Animal containing the Concept Rules *"the*[1] Precedes[1] *dog"* and *"the*[2] Precedes[2] *cat"*;

FIG. **19** is a block diagram of the index-based matcher module shown in FIG. **10**.

FIG. **20** is a block diagram of the synonym processor module shown in FIG. **2** comprising a synonym pruner and synonym optimizer;

FIG. **21** is a block diagram of the synonym processor module shown in FIG. **2** comprising a synonym pruner;

FIG. **22** is a block diagram of the synonym processor module shown in FIG. **2** comprising a synonym optimizer;

FIG. **23** is a block diagram of the synonym pruner module shown in FIG. **20** and FIG. **21** comprising manual ranking, automatic ranking, and synonym filtering;

FIG. **24** is a block diagram of the synonym pruner module shown in FIG. **20** and FIG. **21** comprising manual ranking and synonym filtering;

FIG. **25** is a block diagram of the synonym pruner module shown in FIG. **20** and FIG. **21** comprising automatic ranking and synonym filtering;

FIG. **25a** is a block diagram of the synonym pruner module shown in FIG. **20** and FIG. **21** comprising automatic ranking, human evaluation, and synonym filtering;

FIG. **26** is a block diagram of the synonym optimizer module shown in FIG. **20** and FIG. **22** comprising removal of irrelevant and redundant synonymy relations;

FIG. **27** is a block diagram of the synonym optimizer module shown in FIG. **20** and FIG. **22** comprising removal of irrelevant synonymy relations;

FIG. **28** is a block diagram of the synonym optimizer module shown in FIG. **20** and FIG. **22** comprising removal of redundant synonymy relations;

FIG. **29** is a block diagram of the CSL processor module shown in FIG. **2**;

FIG. **30** is a block diagram of the CSL Concept and Concept Rule learner module shown in FIG. **29** with linguistically annotated documents as input;

FIG. **31** is a block diagram of the CSL Concept and Concept Rule learner module shown in FIG. **29** with text documents as input;

FIG. **32** is a block diagram of the CSL Rule creator module shown in FIG. **30** and FIG. **31**;

FIG. **33** is a block diagram of the CSL query checker module shown in FIG. **29**;

FIG. **34** is a block diagram of the CSL parser module shown in FIG. **2**;

FIG. **35** is a block diagram of the text document retriever module shown in FIG. **2**.

DESCRIPTION

The present invention is described in three sections. Two versions of a method for information retrieval (IR) are described in section 1.

Two versions of a system for IR are described in section 2. One system uses the first method of section 1; the second system uses the second method. The preferred embodiment of the present invention is the second system. Finally, a concept specification language called CSL (short for Concept Specification Language) is described in section 3.

The term "document" herein includes any body of data including text, collection of data including text, storage medium containing textual data or other text-forms.

Method

Two versions of a method for IR are described. The first method uses concept specification languages in general and—though not necessarily—text markup languages in general. The second method uses CSL and—though not necessarily—TML (short for Text Markup Language), a type of text markup language. Both methods can be performed on a computer system or other systems or by other techniques or by other apparatus.

1.1. Method Using concept specification languages and (Optionally) text markup languages

The first IR method uses concept specification languages in general and—though not necessarily—text markup languages in general. That is to say, the first method necessarily uses concept specification languages in general, but does not require the use of a text markup language. The method matches text in documents and other text-forms against user-defined descriptions of concepts, and comprises up to eleven steps, which are now described.

Step (1) is the *identification of linguistic entities in* the *text* of documents and other text-forms. The linguistic entities identified in step (1) include, but are not limited to, morphological, syntactic, and semantic

entities. The identification of linguistic entities in step (1) includes, but is not limited to, identifying words and phrases, and establishing dependencies between words and phrases. The identification of linguistic entities is accomplished by methods including, but not limited to, one or more of the following: preprocessing, tagging, and parsing.

Step (2) is the annotation of those identified linguistic entities from step (1) in, but not limited to, a *text markup language* to produce linguistically annotated documents and other text-forms. The process of annotating the identified linguistic entities from step (1), is known as *linguistic annotation*.

Step (3), which is optional, is the *storage of* these *linguistically annotated documents* and other text-forms.

Step (4) is the *identification of concepts using linguistic information*, where those concepts are represented in a *concept specification language* and the concepts-to-be-identified occur in one of the following forms:

- text of documents and other text-forms in which linguistic entities have been identified as per step (1), or
- the linguistically annotated documents and other text-forms of step (2); or
- the stored linguistically annotated documents and other text-forms of step (3).

A concept specification language allows representations (e.g., rules) to be defined for concepts in terms of a linguistics-based pattern or set of patterns. Each pattern (or phrasal template) consists of words, phrases, other concepts, and relationships between words, phrases, and concepts. For example, the concept *HighWorkload* is linguistically expressed by the phrase *high workload*. In a concept specification language, patterns can be written that look for the occurrence of *high* and *workload* in particular syntactic relations (e.g., *workload* as the subject of *be high*; or *high* and

workload as elements of the same nominal phrase, e.g., *a high but not unmanageable workload*). Expressions can also be written that seek not just the words *high* and *workload*, but also their synonyms.

All methods for identifying concepts work by matching linguistics-based patterns in a concept representation language against linguistically annotated texts. A linguistics-based pattern from a concept representation language is a partial representation of linguistic structure. Each time a linguistics-based pattern matches a linguistic structure in a linguistically annotated text, the portion of text covered by that linguistic structure is considered an instance of the concept.

Methods for identifying concepts can be divided into *non-index-based methods for identifying concepts* and *index-based methods*. Non-index-based methods for identifying concepts include, but are not limited to,

- *compiling* the concept specification language *into finite state automata* (FSAs) and matching those FSAs against linguistically annotated documents,
- *recursive descent matching*, and
- *bottom-up matching*.

Recursive descent matching consists of traversing a concept specification expression and recursively matching its constituents against linguistic structures in annotated text. Bottom-up matching consists of the bottom-up generation of spans for words and constituents from linguistic structures in annotated text, and matching those spans against expression in the concept specification language. (A span is one or more words or constituents that follow each other plus, optionally, structural information about those words and constituents.)

Index-based methods for identifying concepts employ an inverted index. An inverted index contains words, constituents, and (if available) tags for linguistic information present in linguistically annotated

text. The index also contains spans for those words, constituents, and tags from linguistically annotated text.

Index-based methods for identifying concepts include, but are not limited to,

- *simple index-based matching*, and
- *candidate checking index-based matching*.

In simple index-based matching, iterators are attached to all the items in the expression in a concept specification language, then uses index information about the state of each iterator to generate and match spans that, if successful, cover the text selected for concept identification;

In candidate checking index-based matching, sets of candidate spans are identified, where a candidate span is a span that might, but does not necessarily, contain a concept to be identified (matched). Any span that is not covered by a candidate span from the sets of candidate spans is one that cannot contain a concept to be identified (matched). Each sub-expression of an expression in the concept specification language is associated with a procedure, and each such procedure is used to generate candidate spans or to check whether a given span is a candidate span. These candidate spans can serve as input to the four other concept identification methods just described, plus any other concept identification method.

Compiling and matching finite state automata, recursive descent matching, bottom-up matching, and any other possible concept identification method could be made into index-based methods by employing an inverted index.

Step (5) is the annotation of the concepts identified in step (4), e.g., concepts like *HighWorkload*, to produce conceptually annotated documents and other text-forms. (conceptually annotated documents are also sometimes referred to in this description as simply "annotated documents.") The process of annotating the identified concepts from step

(5) is known as *conceptual annotation*. As with step (2), conceptual annotation is in, but is not limited to, a text markup language.

Step (6), which is optional like step (3), is the storage of these conceptually annotated documents and other text-forms.

Steps (7), (8), and (9) are optional and independent of each other and the other steps. Step (7) is *synonym pruning*, which takes some synonym resource as input and establishes a set of domain-specific synonyms of natural language words and phrases for a specific knowledge domain. The pruning method either a manual pruning step or an automatic pruning or a combination of the two, followed by filtering. Manual pruning is applied to the synonymy relations more relevant in the specific domain. A synonymy relation is a relationship between two terms that are not synonyms. Relevance is measured by a score based on the frequency of words in a domain specific corpus.

The method for automatically pruning assigns a score to candidate synonymy relations, based on the frequency of the relevant words, and other semantically related terms, in a domain specific corpus. During filtering, a filtering threshold is set and applied, and all candidates with a score beyond the threshold are eliminated.

Step (8) is *synonym optimization* in which a synonym resource (such as a machine-readable dictionary) is optimized by removing irrelevant sets of synonyms, or redundant sets of synonyms, or both. In optimization, such synonyms are removed in order to increase the accuracy and reduce the size of the synonym resource.

Step (9) is *defining and learning* the *concept representations* of the concept specification language, where the concept representations to be defined and learned include, but are not limited to, hierarchies, rules, operators, patterns, and macros.

Concept representations can be either defined by an operator or acquired (that is, learned) from a corpus. The learning of concept representations from corpora includes, but is not limited to, highlighting instances of concepts in the unprocessed text (or linguistically annotated text) of documents and other text-forms, then creating new concept representations in the concept specification language from those highlighted instances of concepts, then adding and, if necessary, integrating those concept representations in the concept specification language with pre-existing concept representations from the language.

The method of creating new concept representations in step (9) includes, but is not limited to,

- using the concept identification methods of step (4) to match together concept specification language vocabulary specifications and highlighted linguistically annotated documents and other text-forms, then
- defining linguistic variants; then
- adding synonyms from a set of synonyms, possibly supplied by synonym pruning and optimization, and then
- adding part of speech information as appropriate.

Step (10) is *checking user-defined descriptions of concepts* represented in the concept specification language. A common form of checking is *checking user queries* represented in the concept representation language, since user queries are a type of user-defined description of concepts. When checking user queries, those queries are analyzed. Depending on the query content and the current state of knowledge about queries available courtesy of any repositories of pre-stored queries, a decision is made as to the appropriate way to process the incoming user query.

If all known queries are described in the concept representation language, then a proposed query is itself described in the representation language and is subsequently used by the retrieval method of step (11).

If all queries to be described in the concept representation language are not known in advance, then a proposed query is described in the representation language and matched against the repository of pre-stored queries. If a match is found, the query is subsequently used by the method of retrieval. If a match is not found, the proposed query is subsequently sent for concept identification as per step (4).

Step (11) is the *retrieval of text documents* and other text-forms. Retrieval is based on matching user-defined descriptions of concepts (e.g., user queries) against conceptually annotated documents and other text-forms. The format of the output of retrieval depends on the application task for which the system has been configured (e.g., document ranking, document categorization, etc.).

1.2. Method Using CSL and (Optionally) TML

The second IR method uses CSL and—though not necessarily—TML, a type of text markup language. That is to say, the method necessarily uses CSL, but does not require the use of TML.

CSL is a language for expressing linguistically-based patterns. It is comprised of tag hierarchies, Concepts, Concept Rules, Patterns, Operators, and macros. One type of CSL Pattern is a "single-term Pattern" which may refer to the name of a word, and optionally, its part of speech tag (a simple lexical tag or phrasal tag, if a tagger is used), and also optionally, synonyms of the word. Another type of CSL Pattern is a "configurational Pattern." Configurational Patterns may have the form *A* Operator *B*, where the operator can be, among others, a Boolean (such as OR) and can express relationships such as dominance and precedence. Section 3 gives a definition of CSL.

TML presently has the syntax of XML (an abbreviation of (eXtensible Markup Language), though TML isn't required to have the same syntax. A text annotated with TML could be used for a variety of natural

language processing tasks such as information retrieval, text categorization, or even text mining. TML can easily be maintained and modified by non-experts. More lengthy descriptions of TML are given later.

The second method consists of the same basic steps, and relationships among the steps, as the first method. There are two differences between the two methods. The first difference is that wherever a concept specification language is used in the first method, CSL is used in the second. The second difference is that where ever a text markup language is referred to in the first method, TML is used in the second.

Hence, for example, in step (4) of the second method, the concept specification language is CSL and the step consists of identifying CSL Concepts and Concept Rules using linguistic information, *not* identifying the concepts of concept specification languages in general. A preferred embodiment of the second method is given in section 2.3.

2. System

Two versions of an IR system, using a common computer architecture, are described. One system employs the method described in section 1.1; hence it uses concept specification languages in general and—though not necessarily—text markup languages in general. The other system employs the method described in section 1.2; hence it uses CSL and—though not necessarily—TML. The preferred embodiment of the present invention is the second system. First, however, the common computer architecture is described.

2.1. Computer Architecture

FIG. 1 is a simplified block diagram of a computer system embodying the information retrieval system of the present invention. The invention is typically implemented in a client-server configuration including a server **105** and numerous clients connected over a network or other

communications connection **110**. The detail of one client **115** is shown; other clients **120** are also depicted. The term "server" is used in the context of the invention, where the server receives queries from (typically remote) clients, does substantially all the processing necessary to formulate responses to the queries, and provides these responses to the clients. However, the server **105** may itself act in the capacity of a client when it accesses remote databases located on a database server. Furthermore, while a client-server configuration is one option, the invention may be implemented as a standalone facility, in which case client **120** would be absent from the figure.

The server **105** comprises a communications interface **125a** to one or more clients over a network or other communications connection **110**, one or more central processing units (CPUs) **130a**, one or more input devices **135a**, one or more program and data storage areas **140a** comprising a module and one or more submodules **145a** for an information retriever **150** or processes for other purposes, and one or more output devices **155a**.

The one or more clients comprise a communications interface **125b** to a server over a network or other communications connection **110**, one or more central processing units (CPUs) **130b**, one or more input devices **135b**, one or more program and data storage areas **140b** comprising one or more submodules **145b** for an information retriever **150** or processes for other purposes, and one or more output devices **155b**.

2.2. System Using concept specification languages and (Optionally) text markup languages

The first system uses the computer architecture described in section 2.1 and FIG **1**. It also uses the method described in section 1.1; hence it uses concept specification languages in general and—though not necessarily—text markup languages in general. A description of this system can be assembled from sections 1.1. and 2.1. Although not described in

detail within this section, this system constitutes part of the present invention.

2.3. System Using CSL and (Optionally) TML

The second system uses the computer architecture described in section 2.1 and FIG **1**. This system employs the method described in section 1.2; hence it uses CSL and—though not necessarily—TML. The preferred embodiment of the present invention is the second system, which will now be described with reference to FIGS. **2** to **35**. The system is written in the C programming language, but could be embodied in any programming language. The system is an information retriever and is described in section 2.3.1.

2.3.1. Information Retriever

FIG. **2** is a simplified block diagram of the information retriever **206**. The information retriever takes as input text in documents and other text-forms in the form of a signal from one or more input devices **203** to a user interface **212**, and carries out predetermined information retrieval processes to produce a collection of text in documents and other text-forms, which are output from the user interface **212** in the form of a signal to one or more output devices **209**.

The user interface **212** comprises windows for the loading of text documents, the processing of synonyms, the identification of concepts, the definition and learning of concepts, the formulation of user queries, and the viewing of search results.

The predetermined information retrieval processes, accessed by the user interface **212**, comprise a text document annotator **215**, synonym processor **218**, CSL processor **221**, CSL parser **227**, and text document retriever **230**. All these processes are described below. During these

descriptions, all the boxes in FIG. **2** not mentioned in this section will be referred to, e.g., Section 2.3.10. on the synonym processor **218**, refers to the synonym resource **242** and the processed synonym resource **242**.

2.3.2. Text Document Annotator

FIG. **3** is a simplified block diagram of the text document annotator **310**. The text document annotator **310**, accessed by the user interface **305**, comprises a document loader **365** from a document database **315**, which passes text documents **370** to the annotator **375**. The annotator **375** outputs annotated documents **355**.

2.3.3. Annotator

FIG. **4** is a simplified block diagram of the annotator **460**. The annotator **460** takes as input one or more text documents **455** and outputs corresponding documents, where the text is augmented with annotations representing linguistic and conceptual information **440**. The annotator **460** is comprised of a linguistic annotator **465** which passes linguistically annotated documents **425** to a conceptual annotator **470**.

The linguistically annotated documents **425** may be annotated in Text Markup Language (TML) **435** by passing them through a TML converter **430** (or converter for some other markup language), and may be stored **435**.

TML presently has, but is not limited to, the syntax of XML (eXtensible Markup Language), but could have the syntax of any markup language. TML could have any syntax, but the present invention uses the syntax of XML for efficiency reasons. Because TML presently has the syntax of XML, the TML converter used by the system **430** is presently also an XML converter, though the TML converter **430** is not of necessity also an XML converter.

A TML object is a tree-structure, where each node is associated with a label. The top element (i.e., the root of the tree-structure) is a label (e.g., 'TML') identifying the structure as a TML object. In the following we refer to *elements* as nodes in the tree-structure, each of which associated with a label. Each element specifies some kind of object, identified by an appropriate label. Within the top-level node are text elements (associated with a label like 'TEXT', for instance). Within each text element there are a number of sentence elements. Within the sentence elements are grammatical elements, i.e., syntactic constituents comprising a sentence. The grammatical elements are identified by grammatical tags, as assigned by a parser operated by the information retriever (**206** in FIG. **2**). Grammatical elements can have a role element associated with them, i.e., in addition to a label identifying their type of constituent, they can have a further label identifying their role in the sentence (subject, object, etc.). Each grammatical element (constituent) can in turn comprise further constituents. At the bottom of a constituent hierarchy there are text-word elements. Each text-word element has one word in it. Each word has a base element (i.e., a node representing its base form, or lemma), a role element (as previously defined), and a tag element (defining the word's part of speech).

It is not necessary to impose a Document Type Definition (DTD) on TML, unlike other text markup languages that have the syntax of XML, because the DTD would have to duplicate the type definition defined in the grammar used by the system's parser, which would be redundant.

2.3.4. Linguistic Annotator

FIG. **5** is a simplified block diagram of the linguistic annotator **535**. The linguistic annotator **535** takes as input one or more text documents **515**, preprocessing rules (i.e., rewriting rules mapping input text expressions onto corresponding output expressions) **505**, and information from a database of abbreviations **510**. The linguistic annotator **535** outputs one or more linguistically annotated documents **520**. The annotated

information represents linguistic information about the input text documents **515**.

The linguistic annotator **535** is comprised of a preprocessor **550**, tagger **560**, and parser **570**. In the preferred embodiment, all three are used, as shown in FIG. **5**; however, any configuration of these (or any other linguistic identification) as part of the information retriever shown in FIG. **2** is within the scope of the present invention.

2.3.5. Preprocessor

FIG. **6** is a simplified block diagram of the preprocessor **620**. The preprocessor takes as input one or more text documents **615** and outputs one or more preprocessed (or tokenized) documents **655**. The input text is a continuous stream of text. The output is the same text tokenized, i.e., broken into discrete units (words, punctuation, etc.), each augmented with information about its type (word, symbol, number, etc.). The preprocessor performs the following:

a) breaks a continuous stream of text into discrete units (words) **630** using preprocessing rules **605**;
b) marks phrase boundaries **635**;
c) identifies numbers, symbols, and other punctuation **640** using preprocessing rules **605**;
d) expands abbreviations **645** using an abbreviations database **610**; and
e) splits apart contractions **650**.

The preprocessor **620** is responsible for breaking text into words **630** using preprocessing rules **605**. The preprocessor **620** takes as input non-annotated text. It assigns a marker to each word found and outputs words on individual lines separated by a tab character. For instance, the following could be chosen as a set of valid markers:

_num	a number	"one", "2nd" ...
_sym	a symbol	"$", "%", "+" ...
_punct	punctuation	"(" ", " "&" ...
_word	anything else	

The preprocessor **620** is also responsible for marking phrase boundaries **635**. Marking a phrase boundary includes, but is not limited to, identifying sentence final punctuation, such as a period.

The preprocessor **620** identifies numbers, symbols, and other punctuation **640** using preprocessing rules **605**. When sentence final punctuation is found, the preprocessor outputs the punctuation followed by an end of phrase marker "<<EOP>>". Sentence final punctuation is defined by the following: "!", ".", "...", ":", ";", and "?".

The preprocessor **620** employs an abbreviation expander **645**. The expander **645** replaces abbreviations. It works on character strings and returns a string in which the abbreviation is expanded.

The abbreviation expander **645** uses as a knowledge resource an abbreviation database **610**, though it could use other resources. In the abbreviation database **610**, each line contains an abbreviation and its expansion separated by a single tab character.

The preprocessor **620** also splits apart contractions **650**. Contractions are split into separate words. Some examples of contractions split into complete words are shown in Table 1.

TABLE 1

Contraction	Word 1	Word 2
I'm	I	'm
I'd	I	'd
I'll	I	'll

I've	I	've
you're	you	're
don't	do	n't
deans'	deans	s'

2.3.6. Tagger

FIG. **7** is a simplified block diagram of the tagger **708**. The tagger **708** takes as input one or more preprocessed documents **704**, data from a machine-readable morphological dictionary **728** that has been processed by a morphological analyzer **724**, tag information **732**, and lexical probabilities **740** and contextual probabilities **744** from the tagger's datafile **736**. The tagger **708** outputs one or more tagged documents **712**, i.e., the input preprocessed documents **704** augmented with part of speech information for each token in those documents.

The tagger **708** is responsible for assigning an appropriate part of speech from a given tagset to each word given to it (e.g., the UPenn tagset). It is also responsible for determining the base (uninflected) form of the word. The tagger **708** makes use of a tagger datafile **736** produced by a trainer module **748**, and a file which specifies the tags used **732**. The tagger is case-insensitive.

The preprocessed documents **704** are prepared for use **716** by the tagger. The tagger **708** receives as input a word and an optional alternate word as input. The alternate word is tried if the primary word is not present in the lexicon of the tagger datafile. The lexicon is case-insensitive.

The tagger **708** and trainer **748**, work with tag sequences of a given length *n*. The tagger datafile **736** contains lexical probabilities **740** and contextual probabilities **744**. The contextual probabilities **744** refer to tag sequences of the aforementioned length, and represent the conditional probability of a given tag given the preceding tags. Because of this, the tag for a given input

word will not be determined until additional *n* words have been input. Flushing or stopping the tagger will force all input words to be assigned a tag.

Starting the tagger causes it to automatically input *n* leading words called the start gutter. These special words can only have one tag which is the start tag, a special tag not defined in the tagset being used. Flushing or stopping the tagger causes it to input *n* trailing words called the stop gutter. These special words can also only have one tag which is the stop tag, also not defined in the tagset being used. The start and stop gutters do not appear in the output. The reason for the gutters is to improve tagger performance on words that appear at the start and end of phrases.

The tagger operates on the preprocessed documents as follows.

```
- for each phrase
    - reset word fifo queue
    - reset possible tag sequences
    - add start gutter (add three gutter start words as
    - for each input word:
        - add word to queue
        - retrieve possible tags for word from
        - for each tag
            - for each possible tag sequence
            - tack on this tag to the sequence
                - probability of this
        - tag sequences are now A B C D with D
        - find the first sequence with the most
        - group sequences by tags B and C
        - for each group
            - mark the sequence with the most
        - take word from queue
        - take tag A from the overall sequence
        - if word is not a gutter word
                - use morphological analyzer
            - output word, base form, and tag
        - discard all unmarked tag sequences
        - shift tag sequences left, dropping tag A
        - add stop gutter (add three gutter stop
```

For each input word, the tagger outputs the primary word, its base form (as given by a morphological analyzer **724**), and a tag from the tagset being used. This output is added to documents **760**. Final output is a set of tagged documents **712**.

2.3.7. Parser

FIG. **8** is a simplified block diagram of the parser **820**. The parser, which may be a partial parser **840**, takes as input one or more tagged documents **810**, data from tag maps **850** and a grammar **860**, and outputs one or more parsed documents **830**. A linguistically annotated document is a tagged document augmented with syntactic information and other linguistic information for each sentence in the document.

Dependencies are established by parsing. The parser is responsible for assigning a parse structure to input text and assigning roles to the found constituents. Considerations of efficiency and robustness suggest that the best-suited parsers for this purpose, given the current state of the art in parsing, are those collectively known as partial parsers **840**, an instance of which is the partial parser Cass2 produced by Steven Abney. See Abney, S., "Part-of-Speech Tagging and Partial Parsing," In K. Church, S. Young, and G. Bloothooft (Eds.), *Corpus-Based Methods in Language and Speech*. Kluwer Academic Publishers, Dordrecht, The Netherlands (1996).

The partial parser **840** takes as input words, word base forms, and part of speech tag information. On receipt of an end-of-phrase marker the partial parser **840** will parse the input it has received so far.

The partial parser **840** uses as data files tag maps **850** and a grammar **860**. The tag maps contain a mapping from the tagset being used by the tagger (**708** in FIG. **7**) to the internal tagset used by the grammar **860**. The grammar **860** contains the descriptions of the rules to be used by the parser to partial parse the input.

2.3.8. Conceptual Annotator

FIG. **9** is a simplified block diagram of the conceptual annotator **935**. The conceptual annotator **935** takes as input linguistically annotated documents **920**. The linguistically annotated documents **920** may have been stored **930**. The documents may have been stored in TML format **930**. If so, the documents need to be converted **925** back into the internal representations output by the parser (**820** in FIG. **8**).

The conceptual annotator **935** also uses CSL Concepts and Rules for annotation **915** and may also use the parser grammar **950** and synonyms from the processed synonym resource **910**. The conceptual annotator **935** outputs conceptually annotated documents **945**. An annotated document is a linguistically annotated document augmented with labels identifying the occurrences of Concepts and Concept Rules within the document. The conceptual annotator **935** comprises a Concept identifier **940**.

2.3.9. Concept Identifier

FIG. **10** is a simplified block diagram of the Concept identifier **1027**. The Concept identifier **1027** outputs conceptually annotated documents **1021**, which are linguistically annotated documents **1012** augmented with the location of Concepts and Concept Rules in the text of those documents.

Four different techniques are used for concept identification: finite state matching **1063**, recursive descent matching **1066**, bottom-up matching **1069**, and index-based matching **1072**. Which technique is used depends on (1) whether it is desirable to use linguistically annotated documents **1012** that are indexed or non-indexed **1036**, (2) the importance of speed of matching **1039**, (3) the availability of memory resources **1042**, and (4) the expected amount of backtracking.

Input to the Concept identifier **1027** and to all four techniques is linguistically annotated documents **1012**, the processed synonym resource **1006**, and CSL Concepts and Rules for annotation **1009**. Additionally, the grammar from the (partial) parser **1024** is used in finite state matching **1063** and an inverted index **1048** is used in index-based matching **1072**.

The four techniques are described below by explaining how they match a single-term Pattern A, and the operators A Precedes B, A Dominates B, A OR B, and A AND NOT B.

If the data to be matched is non-indexed, then available techniques include, but are not limited to: finite state matching **1063**, recursive descent matching **1066**, and bottom-up matching **1069**. Their use of linguistically annotated documents **1012**, the processed synonym resource **1006**, and CSL Concepts and Rules for annotation **1009** is described. A worked example is given for the text *the cat chased the dog*.

The speed, space requirements and need of backtracking of the different techniques are discussed in their respective subsections.

The following common definitions are assumed throughout the descriptions of the Concept identifier **1027** and the four Concept identification techniques. A "word" is defined as an annotated word or other annotated token that is associated with the text of one or more linguistically annotated documents **1012**. A "constituent" is a syntactic construct such as a noun phrase, which can be represented via a tag or other label. For example, the constituent "noun phrase" might be represented with a tag called NX. Constituents may be found in linguistically annotated documents **1012**.

A "text" is a sequence of words ordered according to the original text of one or more linguistically annotated documents **1012**. A "Text Tree" **1033** is an internal representation, a data structure that implicitly or explicitly contains words and constituents and linguistic relations

between them as described in one or more linguistically annotated documents **1012**. Text Trees **1033** are extracted **1030** from linguistically annotated documents **1012**. FIG. **11** shows a simplified Text Tree **1033** for the text *the cat chased the dog*.

The term "position" refers to a position of a word or constituent in a text. Using the Text Tree **1033** in FIG. **11** as an example, the integer 0 represents the position of the first word *the* in the text, 1 represents the position of the word *cat*, and so forth.

The term "interval" refers to a consecutive sequence of words in a text. An interval can be represented in various ways, for instance, as two integers separated by a dash, where the first integer is the start position; and the second integer is the end position. For example, in the Text Tree **1033** in FIG. **11**, *cat* occupies 1-1, and *the cat* occupies 0-1.

The term "depth" refers to the depth of a word or operator in a representation of text such as a Text Tree **1033**. In FIG. **11**, for example, *the cat* and *chased* have a depth of 2, whereas *the dog* has depth 3.

A "span" is a word or constituent, or alternatively, a set of words and constituents that follow each other, plus (optionally) some structural information about the word(s) and constituent(s). Such structural information includes, but is not limited to, position, interval, or depth information. A span can be represented in various ways, for instance, by integers or by other means. Again using the Text Tree **1033** in FIG. **11** as an example, the span of *the cat* is the interval 0-1 and depth 2.

The inverted index **1048**, which is used in index-based matching **1072**, contains words, constituents, and tags for structural information (e.g., NX) from the linguistically annotated documents **1012** and their spans.

A "Concept Tree" **1054** is a data structure that represents Concepts, Concept Rules and CSL Expressions and their sub-expressions and

their relationships. Concept Trees **1054** are built **1060** from CSL Concepts and Rules for annotation **1009**.

Building Concept Trees **1060** takes as input CSL Concepts and Rules for annotation **1009**. Each Concept and Rule is represented as a Concept Tree **1054**. Build Concept Trees **1060** checks through each tree representation for Concepts. It expands out each Concept into a series of disjunctions, represented in tree form. For example, build Concept Trees **1060** will take a Concept "Animal" that consists of two Rules

Concept:
Concept Rule1: "*the* Precedes *cat*"
Concept Rule2: "*the* Precedes *dog*"

and translates the Concept into the Concept Tree **1054** shown in FIG. **12**.

For the purposes of simpler explanation, Concept Rules are often treated as CSL Expressions that are associated with them. Similarly, Concepts are treated as CSL Expressions that represent disjunctions of their Concept Rules.

2.3.9.1. Finite State Matcher

Finite state matching **1063** takes as input finite state automata (FSAs) **1057** and Text Trees **1033** and produces as output conceptually annotated documents **1021**.

While finite state matching **1063** provides the fastest matching with no backtracking, there is a trade-off between processing time and storage space. Before finite state matching **1063** can be performed, Concept Trees **1054** must first be compiled into finite state automata (FSAs) **1057**. Concept Tree compilation into FSAs **1051** uses considerable storage space.

CSL compilation into FSAs **1051** uses as input Concept Trees **1054** and the processed synonym resource **1006**. It may also use the grammar of the (partial) parser **1024**.

CSL compilation into FSAs **1051** is now explained for a single-term pattern A, and the operators A Precedes B, A Dominates B, A OR B, and A AND NOT B. FSAs for these patterns and operators are shown in FIG. **13** through FIG. **18** below. The FSA generated are non-deterministic. There is no mapping for the AND NOT operator given its current definition.

Each CSL Concept is made up of a number of disjunctive rules, each comprising of a single CSL Expression. These are compiled separately and then added together and simplified using standard FSA techniques. This yields a single FSA representing the Concept.

FSA consist of a number of states and transitions. There is one start state from where the FSA begins, indicated by a circle with an "S". There may be multiple end states, indicated by a circle with an "E", which are the states the automaton must reach in order to succeed.

Traversing transitions consumes input and changes the current state. The transition label "*" will match any input. The label "~WORD" will match any word other than WORD. "~CONSTITUENT" will match anything other than the constituent marker CONSTITUENT.

Compilation of a single-term Pattern A produces the FSA shown in FIG. **13.** The pattern A is a terminal node in a Concept Tree **1054**, where A can be either a word alone or a word and a part-of-speech tag. The FSA has transitions that match a word (or a word and a part-of-speech tag) only if it satisfies all the constraints imposed by the pattern A.

Compilation of A Precedes B produces an FSA shown in FIG. **14**, but only when there is no dominance within a Concept Tree **1054.** Each sub-term (A and B) is mapped recursively.

Compilation into FSAs of the Dominates operator is only possible with an actual Concept Tree **1054**. When there is a dominance operation in the CSL Expression, all productions of the dominating constituent are taken from the partial parser grammar **1024**. The CSL Expression is then matched against these productions. This gives possible values and placements for constituent markers as well as the expression being dominated. Multiple FSA will be produced depending on the number of productions and possible CSL matches. The FSA produced are portions of the partial parser grammar **1024**, converted from regular expressions into FSA, instantiated with the CSL that needs to be matched.

To demonstrate the compilation of the Dominates operator into FSAs, let us assume that the CSL Expression VX dominates *dog* is one of the CSL Concepts and Rules for annotation **1009**. Build Concept Trees **1060** builds the Concept Tree **1054** for this CSL Expression. That Concept Tree **1054** is shown in FIG. **15**.

Let us also assume that the (partial) parser grammar **1024** contained the following rules:

VX = verb NX
NX = noun

Compilation of A Dominates B for these grammar rules **1024** and the Concept Tree **1054** shown in FIG. **15** produces the FSA shown in FIG. **16**.

Compilation of A OR B produces an FSA shown in FIG. **17**, but only when there is no dominance within a Concept Tree **1054**. Each sub-term (A and B) is mapped recursively.

Compilation of the AND NOT operator is not possible.

The resulting FSAs can be simplified using standard FSA techniques that are widely known. The process for traversing a finite state machine (given some text as input) uses standard finite state techniques as implemented in Van Noord, G., *FSA6 Reference Manual* (2000).

Matching occurs by taking the automata for the concepts to be considered and feeding them a flattened Text Tree **1033.**

To see how finite state matching **1063** works, consider how the Text Tree **1033** of FIG. **11** is matched against the Concept Tree **1054** of FIG. **12.** The Concept Tree **1054** is compiled into the FSA shown in FIG. **16.**

The Text Tree **1033** is flattened to:

#CX #NX *the cat* /NX #VX chased #NX *the dog* /NX /VX /CX

The next step is to start feeding the automata until it is able to continue with each word from the flattened text tree. Table 2 shows how input is consumed by traversing the transitions to reach the end state E, signifying success.

TABLE 2

State	Transition	Input
S	-	#CX #NX *the cat* /NX #VX *chased* #NX *the dog* /NX /VX /CX
S	-	#NX *the cat* /NX #VX *chased* #NX *the dog* /NX /VX /CX
S	A	*the cat* /NX #VX *chased* #NX *the dog* /NX /VX /CX
1	C	*cat* /NX #VX *chased* #NX *the dog* /NX /VX /CX
E	-	

2.3.9.2. Recursive Descent Matcher

The advantages of the recursive descent matcher over other matchers include relative simplicity and small space requirements. However, there is a possibility of nontrivial amount of backtracking for certain Concepts.

The recursive descent matcher **1066** takes as input one or more Concept Trees **1054**, one or more Text Trees **1033**, and the processed synonym resource **1006**.

Given a CSL Expression from the Concept Tree **1054**, a Text Tree **1033**, and a position in the text, the recursive descent matching algorithm **1066** can determine whether the CSL Expression matches the text at the given position. It can also determine the span of words that match the CSL Expression. Recursive descent matching **1066** is now explained for a single-term Pattern A, and the operators A Precedes B, A Dominates B, A OR B, and A AND NOT B.

Single-term Pattern A matches at the position if there is a word or a constituent at the position that satisfies all the constraints imposed by the pattern A.

A Precedes B matches at the position if A matches at the position and B matches at a position that follows A. The spans of A and B must not overlap, but can be non-contiguous.

A Dominates B matches at the position if B matches at the position that is within the text spanned by the subtree of A.

A OR B matches at the position if A matches at the position or B matches at the position.

A AND NOT B matches at the position if A matches at the position and B is not found within the span of A.

For an example of how recursive descent matching **1066** works, consider how the Text Tree **1033** of FIG. **11** is matched against the Concept Tree **1054** of FIG. **12.**

The recursive descent matcher **1066** attempts to match a given Concept at each position in the text.

At position 0 (the first instance of the word *the*), the matcher **1066** traverses the Concept Tree **1054** in a top-down fashion. It first encounters the OR operator. It then checks the first sub-expression of OR, which is the Precedes[1] operator. For this operator, the matcher checks its first sub-expression, which is the single-term pattern *the*[1], against the Text Tree **1033**. Since *the*[1] succeeds, the matcher checks the second sub-expression (the single-term pattern *cat*) against the Text Tree **1033,** temporarily incrementing the position in the text. It finds the word *cat*, so the Precedes[1] operator succeeds. Since the first sub-expression of the OR operator has succeeded, there is no need to check the second, and the Concept Tree **1054** (and hence the Concept as a whole) succeeds. Each successful node in the Concept Tree **1054** records the span that it matched to the node above it, so the overall result is the span *the cat*.

The recursive descent matcher **1066** now increments the text position to position 1, which is the position of the word *cat*. The matcher goes through the Concept Tree **1054** until it hits the single-term pattern *the*[1], which doesn't match against the Text Tree **1033.** Then the matcher **1066** tries the other branch of the OR until it also hits the single-term pattern *the*[1], which doesn't match against the Text Tree **1033**, so the match fails at position 1. The matcher **1066** also fails at position 2.

Similarly at position 2 (the word *chased*) the word *the* is not found, so the match fails. However, at position 3 the first branch of the OR fails, but the second branch returns the span *the dog*. The matcher **1066** works in similar fashion through the remainder of the Text Tree **1033,** but no more matches are found.

2.3.9.3. Bottom-up Matcher

The advantage of the bottom-up matcher **1069** is its ability to produce all solutions in a reasonable memory space without backtracking.

The bottom-up matcher **1069** takes as input one or more Concept Trees **1054**, one or more Text Trees **1033**, and the processed synonym resource **1006**.

The matcher **1069** computes spans consumed by single-term patterns and spans consumed by operators from a Concept Tree **1054** in a bottom-up fashion.

For each single-term Pattern A, the algorithm computes the spans that match the pattern by consulting the Text Tree **1033** and selecting spans that satisfy all the constraints imposed by the pattern. Table 3 shows mappings built between single-term Patterns in the Concept Tree **1054** of FIG. **12** and spans for the words of the Text Tree **1033** of FIG. **11**.

TABLE 3

Single-term pattern in Concept Tree	Spans of words in Tex Tree
the[1]	interval 0-0, depth 2; interval 3-3, depth 3
cat	interval 1-1, depth 2
the[2]	interval 0-0, depth 2; interval 3-3, depth 3
dog	interval 4-4, depth 3

For every operator, the bottom-up matcher **1069** builds indices representing the spans of text consumed by that operator. Because the matcher **1069** works in a bottom-up fashion, each operator knows the spans of its arguments. Given spans for their arguments A and B, the spans for different operators can be computed as follows.

A Precedes B. For every pair of spans from A and B, such that the span from A precedes the span from B, output a span that spans the both spans. Set the depth to be the minimum of the two.

A Dominates B. For every pair of spans from A and B, such that the span from A overlaps at a lesser depth than the span from B, output the span from B. For example, in the Text Tree **1033** of FIG. **11**, #CX (interval 0-4, depth 0) dominates #VX (interval 2-4, depth 1).

A OR B. For A and B, output every span that is a span of A or of B.

A AND NOT B. Select all spans from A such that there is no span in B that would be overlapped by the span from A.

The general bottom-up computation can be enhanced with a (possibly) top-down passing of constraints between CSL Expressions. The constraints can be used to limit the number of matches returned and thus to provide more efficient computation.

Table 4 shows mappings built between operators in the Concept Tree **1054** of FIG. **12** and spans for the operators in the Text Tree **1033** of FIG. **11**.

TABLE 4

Operators in Concept Tree	Spans in Text Tree
Precedes^1	interval 0-1, depth 2
Precedes^2	interval 3-4, depth 3; interval 0-4, depth 2; interval 0-4, depth 2
OR	interval 0-1, depth 2; interval 3-4, depth 3

The bottom-up matcher **1069** matches the Concept Tree **1054** against the Text Tree **1033** in the following manner. The matcher **1069** combines the spans for the single-term Pattern *the*^{1} with the spans for the single-term Pattern *cat* to obtain the spans for Precedes^1 operator corresponding to *the*^{1} Precedes^1 *cat*. The matcher **1069** considers possible pairs of spans where the first span comes from the spans of *the*^{1} and the second span comes from the spans of *cat*. The possible pairs are <interval 0-0, depth 2; interval 1-1, depth 2> and <interval 3-3, depth 3; interval 1-1, depth 2>. Only the first pair of spans <interval 0-0, depth 2; interval 1-1, depth 2> satisfies the condition that the first span precedes the second

span. The spans from the pair are combined together to produce a single span <interval 0-1, depth 2> as recorded in Table 4. Similarly, the spans for *the*^{2} are combined with spans for *dog* to produce the spans for the Precedes^2 operator in *the*^{2} Precedes^2 *dog*. The spans for the OR operator are computed as a union of the spans for the two Precedes operators. The results are again shown in Table 4.

2.3.9.4. Index-Based Matcher

FIG. **19** is a simplified block diagram of the index-based matcher **1965**. The index-based matcher **1965** takes as input one or more Concept Trees **1940** and the processed synonym resource **1910**. The index-based matcher **1965** also takes as input an inverted index **1935** of one or more Text Trees **1920**.

An inverted index **1935** contains spans of each word and constituent (e.g., noun phrase) in a Text Tree **1920**. Consider the text *the cat chased the dog* and its Text Tree **1920** shown in FIG. **11**. Table 5 shows an inverted index for that Text Tree **1920**.

TABLE 5

Words and constituents	Spans of words and constituents
#CX	interval 0-4, depth 0
#NX	interval 0-1, depth 1; interval 3-4, depth 2
#VX	interval 2-4, depth 1
the	interval 0-0, depth 2; interval 3-3, depth 3
cat	interval 1-1, depth 2
chased	interval 2-2, depth 2
dog	Interval 4-4, depth 3

The index-based matcher **1965** is faster than matchers that use parse tree-like representations of the linguistically annotated documents.

When Text Trees **1920** are indexed, there remains a choice of at least two index-based matching techniques, depending on the sparseness of Concepts **1970**. The sparseness of Concepts **1970** affects the speed of matching. Candidate checking index-based matching **1980** seems to be

faster for sparsely occurring Concepts, whereas simple index-based matching **1975** seems to be faster for densely occurring Concepts. (Note that it would be straightforward to build an index-based finite state matcher **1063** and an index-based recursive descent matcher **1066**, though we have not elected to do so.)

2.3.9.4.1. Simple Index-Based Matcher

The simple index-based matcher **1975** traverses the Concept Tree **1940** in a recursive depth-first fashion, using backtracking to resolve the constraints of the various CSL operators, until all matches are produced for the items of the Concept Tree **1940** against the text in the inverted index **1935**. Familiarity with the techniques of recursion and backtracking is a necessary prerequisite for understanding this algorithm.

Each node in the Concept Tree **1940** maintains a state that is used to determine whether or not it has been processed before in the match of the Concept Tree **1940** against the inverted index **1940**, and also relevant information about the progress of the match.

The state of nodes for single-item patterns that are words includes the following information: a list of applicable synonyms of the word in question, and the current synonym being used for matching; an iterator into the inverted index **1940** that can enumerate all instances of the word in the index **1940**, and which records the current word.

Nodes for single-term Patterns that are tags and constituents simply maintain iterators into the index, which record the particular instance of the tag or constituent node being used for the current match.

Nodes for Precedence, Dominance, OR and AND NOT operators all record which of their operands have been tried and have been successful in the current match.

During the course of a match, each node is tested, and if successful, returns a set of spans covering the match of its corresponding CSL sub-expression (i.e., all nodes below that node in the Concept Tree **1940**).

To understand how simple index-based matching **1975** proceeds, consider again the text *the cat chased the dog* and its Text Tree **1920** shown in FIG. **11**. The simple index-based matcher **1975** uses the inverted index **1935** for Text Tree **1920**. This inverted index **1935** for Text Tree **1920** is shown in Table 5.

Table 6 shows the span information that the inverted index **1935** has already recorded for those words in Text Tree **1920** shown in FIG. **11**.

TABLE 6

Words	Spans of words
the	interval 0-0; interval3-3
cat	interval 1-1
chases	interval 2-2
dog	interval 4-4

The match begins at the OR operator. The matcher notes that none of the operands have been tried before in the current match, so it picks the first one, a Precedes[1] operator. The matcher notes that the first operand of Precedes[1] has not been tried in this match, so it tries it. The node for the word *the* notes that it has never before been processed, so it initializes its iterator into the inverted index **1935**, and returns a successfully matched span at 0-0. The matcher then processes the second operand of the Precedes[1] operator. This is the word *cat*, and it is successful at 1-1. The matcher then makes sure that the spans returned from the operands satisfy the constraints of a precedence relationship, namely that the first span should precede the second. In this case, the constraints are satisfied, so the Precedes[1] operator is successful with the span 0-1. The OR operator succeeds immediately, since only one of its operands need match, and returns 0-1 as well. Thus the entire match succeeds with the span 0-1.

Then the matcher backtracks. Upon backtracking, the matcher proceeds down the Concept Tree **1940** immediately to the last node it tried – the word *cat*. Upon backtracking, the word node attempts to increment its iterator. Since there are no more instances of the word *cat* in the index, the node fails. The Precedes[1] node then backtracks through its first operand, which is the word *the*. When the word node increments its iterator, it finds the second instance of the word *the*, at 3-3. Then the Precedes[1] node tries its second operand again, whereupon it fails. It then backtracks yet again through its first operand. Since there are no more instances of the word *the*, the word node fails, and the Precedes[1] node finally fails as well. Since the Precedes[1] node has failed, the OR operator tries its other operand. Matching proceeds as above until the second match (at 3-4) is found. Upon further backtracking all the iterators are exhausted and there are no more matches to be found.

2.3.9.4.2. Candidate Checking Index-Based Matcher

The candidate checking index-based matcher **1980** has two parts. The first part identifies candidate spans **1960** that might, but do not necessarily contain, a Concept match. The second part produces (possibly empty) set of matches within the candidate span.

Identifying a candidate span. The purpose of identifying candidate spans **1960** is to weed out pieces of text that cannot contain a Concept match.

A candidate span **1960** is a span that can overlap one or more matches. A candidate span can be as large as the whole text from a single document. The matcher **1980** splits up such a text into smaller texts of a manageable size. For example, the matcher **1980** would split the text

The cat chased the dog. John loves Mary. Peter loves Sandra.

Into the following candidate spans **1960**: *The cat chased the dog* (span 0-4), *John loves Mary* (span 5-7) and *Peter loves Sandra* (span 8-10). (Note that the numbers in these spans ignore the full stops at the end of each sentence.). The iterators introduced in the example below would generate the span 0-4 as the candidate span **1960**. However, spans 5-7 and 8-10 would *not* be generated as candidate spans **1960**.

Consider, as another example, the Concept Tree **1940** in FIG. **12.** Using candidate spans **1960** that correspond to documents, it might be useful to constrain the expensive matching for the Concept Animal to only those documents that contain words *the* and *cat* or that contain words *the* and *dog*. This will save the cost of matching on documents that can never satisfy the matching constraints, because, for example, they do not contain the words *cat* or *dog*.

Each CSL sub-expression from the Concept Tree **1940** is associated with an Iterator. Iterators can be used to generate candidate spans or check whether a given span is a candidate span. The pieces of text that are *not* covered by any of the generated candidate spans are guaranteed to *not* contain matches.

Iterators behave differently with different kinds of CSL Expressions. One of the possible behaviors for the Iterators is given below.

Single-term Pattern A. The inverted index **38** is used to generate or check candidate spans **1960**.

I Precedes I. The only spans returned are those generated as candidate spans **1960** by both Iterators associated with the arguments A and B. Similarly, the only spans checked as candidate spans **1960** are those spans that are also candidate spans **1960** of the Iterators associated with the arguments A and B.

A Dominates B. The behaviour of the Iterator A Dominates B is the same as for A Precedes B.

A OR B. The only spans returned are those generated as candidate spans **1960** by at least one of the Iterators associated with arguments A and B. Similarly, the only spans checked as candidate spans **1960** are those spans that are also candidate spans **1960** of at least one of the Iterators associated with arguments A and B.

A AND NOT B. The only spans returned are those generated as candidate spans **1960** by the Iterator associated with argument A. Similarly, the only spans checked as candidate spans **1960** are those spans that are also candidate spans **1960** of the Iterator associated with argument A.

Consider, for example, how the span is checked that covers the whole Text Tree **1920** for *the cat chased the dog* in FIG. **11**. The OR Iterator succeeds because its first argument, the Precedes[1] Iterator, succeeds when it check its span. The Precedes[1] Iterator succeeds because both of its argument Iterators succeed. Those argument Iterators are the *the*[1] Iterator and the *cat* Iterator. The *the*[1] Iterator succeeds because the input span (for *the cat chased the dog*) overlaps both of the spans for *the*[1] from the inverted index **1935** in Table 6. The span for *the cat chased the dog* is 0-4. The spans for *the*[1] in the inverted index **1935** are 0-0 and 3-3. The *cat* Iterator succeeds for the same reason.

Producing a Set of Matches. The candidate checking matcher **1980** can use any of the other Concept identification techniques described previously—FSA matching **1063**, recursive descent matching **1066**, bottom-up matching **1069**, or simple index based matching **1975**—or any other possible identification techniques to produce the set of matches.

As an example, consider the use of recursive descent matcher **1066** with the text

The cat chased the dog. John loves Mary. Peter loves Sandra.

This text produces the candidate spans **1960** *The cat chased the dog* (span 0-4), *John loves Mary* (span 5-7) and *Peter loves Sandra* (span 8-10).

In its preferred form as described in the Recursive Descent Matcher section (2.3.9.2), the matcher **1066** would try to match the Concept Tree from FIG. **12** to the Text Tree **1920** corresponding to the whole text at every possible position between 0 and 10. However, using the candidate span **1960** information (knowing that matches cannot occur between positions 5-7 and 8-10), recursive descent matching **1066** can be constrained to check the Concept Tree from FIG. **12** only at positions 0, 1, 2, 3 and 4. It is not necessary for the recursive descent matcher **1066** to check positions 5, 6, 7, and 8. Hence, recursive descent matching **1066** can proceed faster.

2.3.10. Synonym Processor

FIG. **20**, FIG. **21**, and FIG. **22** are simplified block diagrams of a synonym processor **2010**, **2110**, and **2210** in various configurations. The synonym processor **2010**, **2110**, and **2210** takes as input a synonym resource **2020**, **2120**, and **2220** such as WordNet, a machine-readable dictionary, or some other linguistic resource. Such synonym resources **2020**, **2120**, and **2220** contain what we call "synonymy relations." A synonymy relation is a binary relation between two synonym terms. One term is a word-sense; the second term is a word that has a meaning synonymous with the first term. Consider, for example, the word *snow*, which has several word senses when used as a noun, including a sense meaning "a form of precipitation" and another sense meaning "slang for cocaine." The former sense of *snow* has a number of synonymous terms including meanings of the words *snowfall* and *snowflake*. The latter sense of *snow* includes meanings of the words *cocaine*, *cocain*, *coke*, and *C*.

Hence, *snowfall* and *snowflake* are in a synonymy relation with respect to the noun-sense of *snow* meaning "a form of precipitation."

FIG. **20** shows the preferred embodiment in which the synonym processor **2030** comprises a synonym pruner **2050** and synonym optimizer **2070**. This is the configuration described in Turcato, D., Popowich, F., Toole, J., Fass, D., Nicholson, D., and G. Tisher, "Adapting a Synonym Database to Specific Domains," In Proceedings of the Association for Computational Linguistics (ACL) '2000 Workshop on Recent Advances in Natural Language Processing and Information Retrieval, 8 October 2000, Hong Kong University of Science and Technology, pp. 1-12 (Oct. 2000), (cited hereafter as "Turcato et al. (2000)"), which is incorporated herein by reference. The rest of the description assumes this configuration, except where stated otherwise.

FIG. **21** and FIG. **22** are simplified block diagrams of the synonym processor **2110** and **2210** in two less favoured configurations. FIG. **21** is a simplified block diagram of the synonym processor **2210** containing just the synonym pruner **2250**. FIG. **22** is a simplified block diagram of the synonym processor **2210** containing just the synonym optimizer **2280**.

2.3.10.1. Synonym Pruner

FIG. **23**, FIG. **24**, and FIG. **25** are simplified block diagrams of the synonym pruner **2315**, **2415**, and **2515** in various configurations. The synonym pruner **2315**, **2415**, and **2515** takes as input a synonym resource **2310**, **2410**, and **2510** such as WordNet, a machine-readable dictionary, or some other linguistic resource. The synonym pruner **2315**, **2415**, and **2515** produces those synonymy relations required for a particular domain (e.g., medical reports, aviation incident reports). Those synonymy relations are stored in a pruned synonym resource **2320**, **2420**, and **2520**.

The synonym resource **2310**, **2410**, and **2510** is incrementally pruned in three phases, or certain combinations of those phases. In the first two phases, two different sets of ranking criteria are applied. These sets of ranking criteria are known as "manual ranking" **2325**, **2425**, and **2525** and "automatic ranking" **2345**, **2445**, and **2545**. In the third phase, a threshold is set and applied. This phase is known as "synonym filtering" **2355**, **2455**, and **2555**.

FIG. **23** shows the preferred embodiment in which the synonym pruner **2315** comprises manual ranking **2325**, automatic ranking **2345**, and synonym filtering **2355**. This is the configuration used by Turcato et al. (2000) cited above. The rest of the description assumes this configuration, except where stated otherwise.

FIG. **24** and FIG. **25** are simplified block diagrams of the synonym pruner **2415** and **2515** in two less favoured configurations. FIG. **24** is a simplified block diagram of the synonym pruner **2415** containing just manual ranking **2425** and synonym filtering **2455**. FIG. **25** is a simplified block diagram of the synonym pruner **2515** containing just automatic ranking **2545** and synonym filtering **2555**.

A variant of FIG **25** is FIG **25a**, in which the automatically ranked synonym resource **2550a** produced by the human evaluation of domain-appropriateness of synonymy relations queries **2545a** is passed to human evaluation of domain-appropriateness of synonymy relations queries **2552a** before input to synonym filtering queries **2555a**.

The manual ranking process **2325** consists of automatic ranking of synonymy relations in terms of their likelihood of use in the specific domain **2330**, followed by evaluation of the domain-appropriateness of synonymy relations by human evaluators **2335**.

The automatic ranking of synonymy relations **2330** assigns a "weight" to each synonymy relation. Each weight is a function of the actual

or expected frequency of use of a synonym term in a particular domain, with respect to a particular sense of a first synonym term. For example, Table 7 shows weights assigned to synonymy relations in the aviation domain between the precipitation sense of *snow* and its synonym terms *cocaine*, *cocain*, *coke*, and *C*.

TABLE 7

Synonymy relation between precipitation sense of *snow* and a synonym term	Weight
cocaine	1
cocain	0
coke	8
C	9168

One possible method and system (of many possible methods and systems) for the automatic ranking of synonymy relations **2330** that may be used with the present invention is described in section 2.2.1 of Turcato et al. (2000). Where no inventory of relevant prior queries exists for the domain then the ranking may be simply in terms of domain corpus frequency. Where an inventory of relevant prior queries exists, then the ranking uses the frequency of the occurrence of the term in the domain corpus and the inventory of query terms to estimate how often a given synonymy relation is likely to be used.

The set of synonymy relations and their weights are then ranked from greatest weight to least, and then presented in that ranked order to human evaluators for assessment of their domain-appropriateness **2335**. The weights are useful if there are insufficient evaluators to assess all the synonymy relations, as is frequently the case with large synonym resources **2310**. In such cases, evaluators begin with the synonymy relations with greatest weights and proceed down the rank-ordered list, assessing as many synonymy relations as they can with the resources they have available.

The judgement of appropriateness of synonymy relation in a domain might be a rating in terms of a binary Yes-No or any other rating

scheme the evaluators see fit to use (e.g., a range of appropriateness judgements).

The output of manual ranking **2325** is a manually ranked synonym resource **2340**. The manually ranked synonym resource **2340** is like the synonym resource **2310**, except that the synonymy relations have been ranked in terms of their relevance to a specific application domain. No synonymy relations are removed during this phase.

In the second phase of the preferred embodiment shown in FIG. **23**, the manually ranked synonym resource **2340** is automatically ranked **2345**. Automatic ranking **2345** is based on producing scores representing the domain-appropriateness of synonymy relations. The scores are produced from the frequencies in a domain-specific corpus of the words involved in the synonymy relation, and the frequencies of other semantically related words. Those words involved in the synonymy relation are presently, but need not be limited to, terms from the lists of synonyms and dictionary definitions for words. Other semantically related words include, but need not be limited to, superordinate and subordinate terms for words.

One possible method and system (of many possible methods and systems) for the automatic ranking of the domain-appropriateness of synonymy relations **2345** that may be used with the present invention is described in section 2.3 of Turcato et al. (2000).

The output of automatic ranking **2345** is an automatically ranked synonym resource **2350** of the same sort as the manually ranked synonym resource **2340**, with the ranking scores attached to synonymy relations. Again, no synonymy relations are removed during this phase.

In synonym filtering **2355**, a threshold is set **2360** and applied **2365** to the automatically ranked synonym resource **2350**, producing a filtered synonym resource **2370**. It is during this phase of synonym pruning **2360** that synonymy relations are removed.

The threshold setting **2360** in the preferred embodiment is flexible and set by the user through a user interface **2305**, though neither needs to be the case. For example, the threshold could be fixed and set by the system developer or the threshold could be flexible and set by the system developer.

The three phases just described can be configured in ways other than the preferred embodiment just described. Firstly, strictly speaking, automatic pruning **2345** could be performed manually, though it would require many person-hours on a synonym resource **2310** of any size. Second, in the preferred embodiment, the pruned synonym resource **2310** is the result of applying two rounds of ranking. However, in principle, the pruned synonym resource **2320** could be the result of just one round of ranking: either just manual ranking **2425** as shown in FIG. **24** or just automatic ranking **2545** as shown in FIG. **25**.

2.3.10.2. Synonym Optimizer

FIG. **26**, FIG. **27**, and FIG. **28** are simplified block diagrams of the synonym optimizer **2610**, **2710**, and **2810** in various configurations. Input to of the synonym optimizer **2610**, **2710**, and **2810** is either an unprocessed synonym resource **2620**, **2720**, and **2820** or a pruned synonym resource **2630**, **2730**, and **2830**. The input is a pruned synonym resource **2630**, **2730**, and **2830** in the preferred embodiment of the synonym processor (shown in FIG. **20**). The input is an unprocessed synonym resource **2620**, **2720**, and **2820** for one of the other two configurations of the synonym processor (shown in FIG. **22**).

Output is an optimized synonym resource **2650**, **2750**, and **2850**.

The synonym optimizer **2610**, **2710**, and **2810** identifies synonymy relations that can be removed that, if absent, either do not affect or minimally affect the behaviour of the system in a specific domain. It consists of two phases that can be used either together or individually. One

of these phases is the removal of irrelevant synonymy relations **2660** and **2760**; the other is the removal of redundant synonymy relations **2670** and **2870**.

FIG. **26** shows the preferred embodiment in which the synonym optimizer **2610** comprises both the removal of irrelevant synonymy relations **2660** and the removal of redundant synonymy relations **2670**. This is the configuration used by Turcato et al. (2000). The rest of the description assumes this configuration, except where stated otherwise.

FIG. **27** and FIG. **28** are simplified block diagrams of the synonym optimizer **2710** and **2810** in two less favoured configurations. FIG. **27** is a simplified block diagram of the synonym optimizer **2710** containing just the removal of irrelevant synonymy relations **2760**. FIG. **28** is a simplified block diagram of the synonym optimizer **2810** containing just the removal of redundant synonymy relations **2870**.

The removal of irrelevant synonymy relations **2660** eliminates synonymy relations that, if absent, either do not affect or minimally affect the behaviour of the system in a particular domain. One criterion for the removal of irrelevant synonymy relations **2660** is: a synonymy relation that contains a synonym term that has zero actual or expected frequency of use in a particular domain with respect to a particular sense of a first synonym term. For example, Table 1 shows weights assigned in the aviation domain for synonymy relations between the precipitation sense of *snow* and its synonym terms *cocaine*, *cocain*, *coke*, and *C*. The table shows that the synonym term *cocain* has weight 0, meaning that *cocain* has zero actual or expected frequency of use as a synonym of the precipitation sense of *snow* in the aviation domain. In other words, the synonymy relation (precipitation sense of *snow*, *cocain*) in the domain of aviation can be removed.

Note that the criterion for removing a synonym term need not be zero actual or expected frequency of use. When synonym resources are very large, an optimal actual or expected frequency of use might be one or

some other integer. In such cases, there is a trade-off. The higher the integer used, the greater the number of synonymy relations removed (with corresponding increases in efficiency), but the greater the risk of a removed term showing up when the system is actually used.

In most cases, users will accept that irrelevant synonym terms are those with zero actual or expected frequency of use. However, the user interface **2640** allows users to set their own threshold for actual or expected frequency of use, should they want to.

A possible method and system (of many possible methods and systems) for the removal of irrelevant synonymy relations **2660** that may be used with the present invention is described in section 2.4.1 of Turcato et al. (2000). In particular, terms which never appear in the domain corpus are considered to be irrelevant. If the domain corpus is sufficiently large, then terms which appear in a low frequency may still be considered to be irrelevant.

The removal of redundant synonymy relations **2670** eliminates redundancies among the remaining synonymy relations. Synonymy relations that are removed in this phase are again those that can be removed without affecting the behaviour of the system.

A possible method and system (of many possible methods and systems) for the removal of redundant synonymy relations **2670** that may be used with the present invention is described in section 2.4.2 of Turcato et al. (2000). In particular, sets of synonyms which contain a single term (namely the target term itself) are removed as are sets of synonyms which are duplicates, namely are identical to another set of synonyms in the resource which has not been removed.

The output of optimization **2610** is an optimized synonym resource **2650**, which is of the same sort as the unprocessed synonym resource **2620** and pruned synonym resource **2620**, except that synonymy

relations that are irrelevant or redundant in a specific application domain have been removed.

Note that optimization **2610** could be used if the only synonym resource to be filtered **2355** was the manually ranked synonym resource **2340** produced by manual ranking **2325** within synonym pruning **2305.** Indeed, optimization **2610** would be pretty much essential if manual ranking **2325** and filtering **2355** was the only synonym pruning **2305** being performed. Optimization **2610** could also in principle be performed between manual ranking **2325** and automatic ranking **2345**, but little is gained from this because irrelevant or redundant synonymy relations in the manually ranked synonym resource **2340** do not affect automatic pruning **2345.**

2.3.11. CSL Processor

FIG. **29** is a simplified block diagram of the CSL processor **2910.** The CSL processor **2910**, accessed by the user interface **2905**, comprises a CSL Concept and Concept Rule learner **2985** and a CSL query checker **2990.**

2.3.12. CSL Concept and Concept Rule Learner

FIG. **30** and FIG. **31** are simplified block diagrams of the CSL Concept and Concept Rule learner **3075** and **3175.**

The CSL Concept and Concept Rule learner **3075** and **3175**, accessed by the user interface **3005** and **3105**, takes as input a text corpus in which instances of a given concept have been highlighted **3045** and **3135**, and it outputs a list of CSL Concepts and Concept Rules **3070** and **3195**, covering the occurrences marked up in the input corpus. The CSL Concept and Concept Rule learner **3075** and **3175** comprises two main internal methods: highlighted linguistically annotated documents **3050** and **3150** are passed to a CSL Rule creator **3055** and **3160** which produces CSL Rules **3060** and **3165.** These CSL Rules **3060** and **3165** are input to a method

that creates CSL Concepts from Concept Rules **3065** and **3170**, which outputs a list of CSL Concepts and Concept Rules **3070** and **3195**.

FIG. **30** and FIG. **31** present two different ways that instances of concepts may be highlighted. In FIG. **30**, the CSL Concept and Concept Rule learner **3075** comprises first of all the highlighting of instances of concepts **3045** in the text of linguistically annotated documents **3015** to produce highlighted linguistically annotated documents **3050**. Those linguistically annotated documents **3015** may be converted to TML **3020** (or some other format) and may also be stored **3025**. Those highlighted linguistically annotated documents **3050** may also be converted to TML **3020** (or some other format) and may also be stored **3085**.

In FIG. **31**, the CSL Concept and Concept Rule learner **3175** comprises first of all the highlighting of instances of concepts **3135** in the text of documents **3115** to produce highlighted text documents **3125**. The linguistic annotator **3145** processes those highlighted documents **3125** to produce highlighted linguistically annotated documents **3150**. Those highlighted text documents **3125** may be converted to TML **3120** (or some other format) and may also be stored **3140**. The highlighted linguistically annotated documents **3150** may also be converted to TML **3120** (or some other format) and may also be stored **3155**.

2.3.13. CSL Rule Creator

FIG. **31** is a simplified block diagram of the CSL Rule creator **3245**. The CSL Rule creator **3245** takes as input CSL vocabulary specifications **3230** and highlighted linguistically annotated documents **3215** and outputs CSL Rules **3240**. The CSL vocabulary specifications **3230** and highlighted linguistically annotated documents **3215** are matched together using the Concept identifier **3250**. Then linguistic variants are defined **3255**; synonyms **3255** are added from a processed synonym resource **3210** (if available), and parts of speech **3260** are also added before CSL Rules **3240** are produced.

2.3.14. CSL Query Checker

FIG. **33** is a simplified block diagram of the CSL query checker **3355**. The CSL query checker **3355**, accessed by the user interface **3305**, takes as input a proposed CSL query **3315** and, if all queries are known in advance **3360**, passes that query (a concept label) **3330a** to the retriever **3350**. The retriever **3350** is part of the text document retriever **3545** (see FIG. **35**).

If all queries are not known in advance **3360**, the CSL query checker **3355** matches **3365** the proposed query **3315a** against known CSL Concepts and Concept Rules **3325** and, if a match is found **3370**, the query (a CSL expression) **3330b** is parsed **3320** and passed to the retriever **3350**, else the query (also a CSL expression) **3330b** is parsed **3320** and added to the list of CSL Concepts and Concept Rules to be annotated **3335**, which are then passed to the annotator **3345**.

2.3.15. CSL Parser

FIG. **34** is a simplified block diagram of the CSL parser **3425**. The CSL parser **3425** takes as input a CSL query **3430** (**3330b** from FIG. **33**), CSL Concepts and Rules **3410**, and a processed synonym resource **3405**, if available. It outputs CSL Concepts and Rules for annotation **3415** and also outputs parsed CSL queries for retrieval **3420**. In the output, information left implicit in the input CSL Rules (e.g., about possible tags and synonyms) is made explicit.

The CSL parser **3425** comprises word compilation **3435**, CSL Concept compilation **3440**, downward synonym propagation **3445**, and upward synonym propagation **3450**.

Concepts are parsed as follows. Word synonyms (from the processed synonym resource **3405**) are propagated throughout the tag hierarchy. This lets the input describe a word as a noun and have its

synonyms automatically defined for both singular and plural nouns, assuming that the tag hierarchy contains a tag for noun with children tags for singular and plural nouns. The levels above noun would also automatically contain the synonyms for noun, but they would be marked such that the words would only match if they are tagged as nouns.

A processed synonym resource **3405** (derived from, e.g., WordNet) provides synonyms for words at levels in the tag hierarchy that are referenced. (Synonyms are only propagated to levels in the tag hierarchy that are referenced.)

In word compilation **3435**, each word is compiled into a suitable structure.

In Concept compilation **3440**, each Concept is compiled into a suitable structure. For every Concept, a word structure is added for each reference to an undefined word.

In downward synonym propagation **3445**, for every word, synonyms are propagated down the tag hierarchy. Synonyms that move down take on the tag value given by the position in the hierarchy.

In upward synonym propagation **3450**, for every word, synonyms are propagated up the tag hierarchy. Synonyms that move up take on a combination of the tag values given by the positions that they came from in the hierarchy.

2.3.16. Text Document Retriever

FIG. **35** is a simplified block diagram of the text document retriever **3545**. The text document retriever **3545**, accessed by the user interface **3505**, comprises a retriever **3550**. The retriever **3550** takes as input annotated documents **3520** (that is, conceptually annotated documents) and a CSL query for retrieval **3515**.

The annotated documents **3520** contain the names of Concepts that were matched by the Concept identifier during conceptual annotation (**940** and **935** respectively in FIG. **9**). If the Concept identifier was index-based, the annotated documents **3520** also contain inverted index information. The retriever **3550** searches through the annotated documents **3520** for the names of Concepts that match specific CSL expressions in a CSL query for retrieval **3515**.

The retriever **3550** produces retrieved documents **3555** and categorized documents **3530**. Categorized documents **3530** used for retrieval **3550** may have been stored **3535** and may have been converted from TML **3510** or some other format. Similarly, categorized documents **3530** discovered during retrieval **3550** may be stored **3535** and may have been converted from TML **3510** or some other format. Retrieved documents **3555** have the same storage and conversion possibilities (**3510** and **3540**).

The retriever **3550** passes retrieved documents **3555** and categorized documents **3530** to a document viewer **3560** accessed by the user interface **3505**.

3. Concept Specification Language

This section contains a description of the syntax of CSL. CSL is a language for expressing linguistically-based patterns. It is comprised of tag hierarchies, Concepts, Concept Rules, Patterns, Operators, and macros.

A tag hierarchy is a set of declarations. Each declaration relates a tag to a set of tags, declaring that each of the latter tags is to be considered an instance of the former tag.

A Concept in the CSL is used to represent concepts. A Concept can either be global or internal to other Concepts. A Concept uses words and other Concepts in the definition of Concept Rules.

A Concept Rule comprises an optional name internal to the Concept followed by a Pattern.

A Pattern may match

a) single terms in an annotated text (a "single-term Pattern") or

b) some configuration in an annotated text (a "configurational Pattern").

A single-term Pattern may comprise a reference to

a) the name of a word, and optionally,

b) its part of speech tag (a simple lexical tag or phrasal tag), and optionally,

c) synonyms of the word.

A configurational Pattern may consist of the form *A* Operator *B*, where the Operator is Boolean:

A configuration is any expression in the notation used to represent syntactic descriptions (for instance, trees or labelled bracketing).

A configurational Pattern may consist of the form *A* Operator *B*, where the Operator is of two types:

a) Dominance, and

b) Precedence.

A configurational Pattern may consist of the form *A* Dominates *B*, where

a) *A* is a syntactic constituent (which can be identified by a phrasal tag, though not necessarily);

b) *B* is any Pattern

(the entire Pattern matches any configuration where what *B* refers to is a subconstituent of *A*).

A configurational Pattern *A* Dominates *B* may be "wide-matched," meaning that the interval of *A* in a text is returned instead of *B*; that is, the interval of a dominant expression (*A*) is returned rather than the interval of a dominated expression (*B*). The term "interval" was defined earlier as referring to a consecutive sequence of words in a text. An interval can be represented in various ways, for instance, as two integers separated by a dash, where the first integer is the start position; and the second integer is the end position. For example, in the Text Tree in FIG. **11**, *cat* occupies 1-1, and *the cat* occupies 0-1.

A configurational Pattern may consist of the form *A* Precedes *B*, where

a) *A* is any Pattern;

b) *B* is any Pattern

(the entire Pattern matches any configuration where the constituent *A* refers to is before the constituent *B* refers to).

Boolean operators can be applied to any Patterns to obtain further Patterns.

Any of the Patterns thus defined is a CSL Expression.

A Pattern is fully recursive (i.e., subject to Patterns satisfying the arguments of the Operators defined above).

A Macro in the CSL represents a Pattern in a compact, parameterized form and can be used wherever a Pattern is used.

What is claimed is:

1. A method of information retrieval, performed on a computer system that matches text in documents against user-defined descriptions of concepts, comprising:

a) identification of linguistic entities in the text of documents;

b) annotation of said identified linguistic entities in a text markup language to produce linguistically annotated documents;

c) identification of concepts using linguistic information, where said concepts are represented in a concept specification language and said concepts occur in one of:

   1) said text of documents in which linguistic entities have been identified; or

   2) said linguistically annotated documents; or

   3) said stored linguistically annotated documents;

d) annotation of said identified concepts in said text markup language to produce conceptually annotated documents;

e) checking user-defined descriptions of concepts represented in said concept specification language; and

f) retrieval by matching said user-defined descriptions of concepts against said conceptually annotated documents.

2. The method according to claim 1 wherein said identification of linguistic entities in the text of documents comprises morphological, syntactic, and semantic entities.

3. The method according to claim 2 wherein said identification of linguistic entities in the text of documents comprises

identifying words and phrases, and establishing dependencies between words and phrases.

4. he method according to claim **3** wherein said identification of linguistic entities in the text of documents and other text-forms is accomplished by a method selected from one or more of :

a) preprocessing of text of documents;

b) tagging of text of documents;

c) parsing of text of documents.

5. The method according to claim **4** wherein annotation of said identified linguistic entities in the text of documents and other text-forms is known as linguistic annotation and produces a representation of linguistically annotated documents in a text markup language.

6. The method according to claim **5** wherein said linguistically annotated documents are stored.

7. The method according to claim **1** wherein said identification of concepts using linguistic information, where said concepts are represented in a concept specification language and said concepts occur in one of:

a) said text of documents in which linguistic entities have been identified as per claim **4**, or

b) said linguistically annotated documents and other text-forms of claim **5**; or

c) said stored linguistically annotated documents and other text-forms of claim **6**.

8. The method according to claim **7** wherein said concept specification language allows representations to be defined for concepts in terms of a linguistics-based pattern or set of patterns, where each pattern consists of words, phrases, other concepts, and relationships between words, phrases, and concepts.

9. The method according to claim **8** wherein said identification of concepts using linguistic information, when used with said concept specification language, consists of applying representations of concepts for the purpose of identifying concepts.

10. The method according to claim **7** wherein annotation of said identified concepts in linguistically annotated documents is known as conceptual annotation and produces a representation of conceptually annotated documents in a text markup language.

11. The method according to claim **7** wherein said identification of concepts uses linguistic information, and said concepts are represented in a concept specification language, as a result of methods for identifying concepts comprising:

a) compiling an expression from said concept specification language into finite state automata (FSAs);

b) matching said FSAs against linguistic entities in said linguistically annotated text.

12. The method according to claim **11** wherein concepts from said concept specification language are compiled into finite state automata (FSAs), said compilation into FSAs comprises one or both of the following:

a) the grammar from the parser used within the method to parse linguistically annotated text; and

b) sets of synonyms.

13. The method according to claim **7** wherein said identification of concepts uses linguistic information, and said concepts are represented in a concept specification language, as a result of methods for identifying concepts comprises recursive descent matching which consists of traversing an expression in said concept specification language and recursively matching constituents of said expression against linguistic entities in linguistically annotated text.

14. The method according to claim **13** wherein identification of concepts using recursive descent matching , where recursive descent matching comprises sets of synonyms.

15. The method according to claim **7** wherein said identification of concepts uses linguistic information, and said concepts are represented in a concept specification language, as a result of methods for identifying concepts which comprise bottom-up matching comprising:

a) generating in a bottom-up fashion multiple spans, where each span is a word or constituent, or alternatively, a set of words and constituents that follow each other, plus structural information about the word and constituent;

b) generating in a bottom-up fashion spans consumed by single-term patterns in an expression in said concept specification language;

c) generating in a bottom-up fashion spans consumed by operators (such as A Precedes B and A OR B) in an expression in said concept specification language; and.

d) matching in a bottom-up fashion said spans against linguistic entities in linguistically annotated text.

16. The method according to claim **15** wherein said identification of concepts uses bottom-up matching, where bottom-up matching comprises sets of synonyms.

17. The method according to claim **7** wherein said identification of concepts uses linguistic information, and said concepts are represented in a concept specification language, as a result of methods for identifying concepts that are index-based comprising use of an inverted index, where

a) said inverted index contains words, constituents, and tags for linguistic information, comprising syntactic information, from linguistically annotated text;

b) said inverted index contains spans for said words, constituents, and tags from linguistically annotated text;

c) where a span is a word or constituent, or alternatively, a set of words and constituents that follow each other, and structural information about the word and constituent.

18. The method according to claim **17** wherein said identification of concepts uses linguistic information, and said concepts are represented in a concept specification language, as a result of index-based methods for identifying concepts comprising index-based matching, where said index-based matching comprises:

a) using backtracking to resolve the constraints of operators (such as A Precedes B and A OR B) in an expression in said concept specification language;

b) attaching iterators to all items in the expression in said concept specification language;

c) using the iterators to produce matches of all items in the expression in said concept specification language against text in the inverted index;

d) maintaining a state for the iterator for each item in the expression in said concept specification language where that state is used to determine whether or not it has been processed before in the match of said expression against said inverted index, and also relevant information about the progress of the match;

e) maintaining a state for the iterator for each item that is a word in the expression in said concept specification language where that state includes, but is not limited to, the following information: a list of applicable synonyms of the word in question, and the current synonym being used for matching; an iterator into the inverted index that can enumerate all instances of the word in said index, and which records the current word;

f) during the course of a match, each item in the expression in said concept specification language is tested, and if successful, returns a set of spans covering the match of its corresponding sub-expression.

19. The method according to claim **18** wherein identification of concepts uses index-based matching, where index-based matching comprises sets of synonyms.

20. The method according to claim **17** wherein said identification of concepts uses linguistic information, and said concepts are represented in a concept specification language, as a result of index-based methods for identifying concepts comprising candidate checking index-based matching where said candidate checking index-based matching comprises identifying sets of candidate spans, where

a) a candidate span is a span that might, but does not necessarily, contain a concept to be identified;

b) any span that is not covered by a candidate span from the sets of candidate spans is one that cannot contain a concept to be identified;

c) each sub-expression of an expression in the concept specification language is associated with a procedure;

d) each such procedure is used to generate candidate spans or to check whether a given span is a candidate span.

21. The method according to claim **20** wherein said identification of concepts uses linguistic information, and said concepts are represented in a concept specification language, as a result of index-based methods for identifying concepts comprising candidate checking index-based matching where said candidate checking index-based matching produces candidate spans that serve as input to concept identification methods comprising compiling and matching finite state automata, recursive descent matching, bottom-up matching, and index based matching.

22. The method according to claim 7 wherein said identification of concepts uses linguistic information, and said concepts are represented in a concept specification language, as a result of methods for identifying concepts comprising using an inverted index with compiling and matching finite state automata, recursive descent matching, bottom-up matching, and simple index based matching, and any other possible concept identification methods.

23. The method according to claim 10 wherein said conceptually annotated documents are stored.

24. The method according to claim 1 wherein said concept representations to be defined and learned include, but are not limited to, hierarchies, rules, operators, patterns, and macros.

25. The method according to claim 1, further comprising the step of defining and learning said concept representations of said concept specification language comprises:

a) marking up instances of concepts in the text of documents;

b) creating new concept representations in the concept specification language from said highlighted instances of concepts;

c) adding and, if necessary, integrating said new concept representations in the concept specification language with pre-existing concept representations in said language.

26. The method according to claim 25 wherein creating new concept representations of said concept specification language comprises:

a) using concept identification methods to match together concept specification language vocabulary specifications and highlighted linguistically annotated documents and other text-forms;

b) defining linguistic variants;

c) adding synonyms from a set of synonyms;

d) adding parts of speech.

27. The method according to claim **1** further comprising the step of defining and learning said concept representations of said concept specification language comprising:

a) highlighting instances of concepts in the text of linguistically annotated documents to produce highlighted linguistically annotated documents; where

b) said linguistically annotated documents are stored or produced on demand; and

c) said highlighted linguistically annotated documents are stored or produced on demand;

d) producing new concept representations in the concept specification language from said highlighted instances of concepts in said highlighted linguistically annotated documents; and

e) adding and, if necessary, integrating said new concept representations in the concept specification language with pre-existing concept representations in said language.

28. The method according to claim **1** further comprising the step of defining and learning said concept representations of said concept specification language comprising:

a) marking up instances of concepts in the text of documents to produce highlighted documents;

b) identification of linguistic entities in said highlighted documents and annotation of said documents to produce highlighted linguistically annotated documents;

c) said highlighted text documents, but are not limited to being, stored or produced on demand;

d) said highlighted linguistically annotated documents are stored or produced on demand;

e) producing new concept representations in the concept specification language from said highlighted instances of concepts in said highlighted linguistically annotated documents; and

f) adding and, if necessary, integrating said new concept representations in the concept specification language with pre-existing concept representations in said language.

29. The method according to claim **1** wherein said user-defined descriptions of concepts represented in said concept specification language comprise user queries to an information retrieval system, said user queries being represented in said concept specification language.

30. The method according to claim **29** wherein, if all known queries are represented in said concept specification language, then a proposed query represented in said concept specification language is subsequently used by said retrieval method.

31. The method according to claim **29** wherein, if all queries are not known in advance to be represented in said concept specification language, then a proposed query represented in said concept specification language is matched against a pre-stored repository of queries represented in said concept specification language and, if a match is found, then the query is subsequently used by said method of retrieval.

32. The method according to claim **29** wherein, if all queries are not known in advance to be represented in said concept specification language, then a proposed query represented in said concept specification language is matched against a pre-stored repository of queries represented in said concept specification language and, if a match is not found, then the query is subsequently used by said method of conceptual annotation.

33. The method according to claim **29** wherein retrieval matches said user-defined descriptions against said annotated text and retrieves matching documents.

34. A method for information retrieval, performed on a computer system that matches text in documents and other text-forms against user-defined descriptions of concepts, comprising:

a) identification of linguistic entities in the text of documents;

b) annotation of said identified linguistic entities in, but not limited to, a Text Markup Language (TML) to produce linguistically annotated documents;

c) storage of said linguistically annotated documents;

d) identification of Concepts and Concept Rules using linguistic information, where said Concepts and Concept Rules are represented in a Concept Specification Language (CSL) and said Concepts-to-be-identified and Concept Rules-to-be-identified occur in one of:

1) said text of documents in which linguistic entities have been identified as per a), or

2) said linguistically annotated documents of b); or

3) said stored linguistically annotated documentsof c);

e) annotation of said identified Concepts and Concept Rules in said TML to produce conceptually annotated documents;

f) storage of said conceptually annotated documents;

g) defining and learning CSL Concepts and Concept Rules;

h) checking user-defined descriptions of Concepts and Concept Rules represented in CSL; and

i) retrieval by matching said user-defined descriptions of CSL Concepts and Concept Rules against said conceptually annotated documents.

35. A computer system for implementing said methods according to claims **1** or **34**, located on a server, comprising a communications interface to one or more clients over a network or other communication connection, one or more central processing units (CPUs), one or more input devices, one or more program and data storage areas comprising a module and one or more submodules for an information retriever or processes for other purposes, and one or more output devices.

36. A computer system for implementing said methods according to claims **1** or **34**, located on one or more clients, comprising a communications interface to a server over a network or other communication connection, one or more central processing units (CPUs), one or more input devices, one or more program and data storage areas comprising one or more submodules for an information retriever or processes for other purposes, and one or more output devices.

37. The computer system of claims **35** or **36** wherein the information retriever takes as input text in documents in the form of a signal from one or more input devices to a user interface, and carries out predetermined information retrieval processes to produce a collection of text in documents, which are output from the user interface in the form of a signal to one or more output devices.

38. The system according to claim **37** wherein predetermined information retrieval processes, accessed by said user interface, comprises:

a) identification of linguistic entities in the text of documents;

b) annotation of said identified linguistic entities in a text markup language to produce linguistically annotated documents;

c) storage of said linguistically annotated documents and other text-forms;

d) identification of concepts using linguistic information, where said concepts are represented in a concept specification language and said concepts to be identified occur in one of:

1) said text of documents in which linguistic entities have been identified as per a), or
2) said linguistically annotated documents of b); or
3) said stored linguistically annotated documents of c);

e) annotation of said identified concepts in said text markup language to produce conceptually annotated documents;

f) storage of said conceptually annotated documents;

g) defining and learning concept representations of said concept specification language;

h) checking user-defined descriptions of concepts represented in said concept specification language; and

i) retrieval by matching said user-defined descriptions of concepts against said conceptually annotated documents.

39. The system according to claim **37** wherein predetermined information retrieval processes, accessed by said user interface, comprise a text document annotator, synonym processor, CSL processor, CSL parser, and text document retriever.

40. The system according to claim **39** wherein said text document annotator, accessed by said user interface, comprises a document loader from a document database, which passes text documents to the annotator, and outputs one or more annotated documents.

41. The system according to claim **40** wherein said annotator takes as input one or more text documents, outputs one or more

annotated documents, and is comprised of a linguistic annotator which passes linguistically annotated documents to a conceptual annotator.

42. The system according to claim **41** wherein said linguistically annotated documents are annotated with a representation in a Text Markup Language.

43. The system according to claim **41** wherein said Text Markup Language (TML) has the syntax of XML, and hence that conversion to and from TML is accomplished with an XML converter.

44. The system according to claim **41** wherein said linguistic annotator, taking as input one or more text documents, and outputting one or more linguistically annotated documents, comprises one or more of the following:

a) a preprocessor;
b) a tagger;
c) a parser.

45. The system according to claim **44** wherein said preprocessor, taking as input one or more text documents (or the documents output by any other appropriate linguistic identification process) and outputting one or more preprocessed documentscomprises one or more of the following:

a) breaking text into words;
b) marking phrase boundaries;
c) identifying numbers, symbols, and other punctuation;
d) expanding abbreviations; and
e) splitting apart contractions.

46. The system according to claim **44** wherein said tagger takes as input a set of tags, one or more preprocessed documents and outputs one or more documents tagged with the appropriate part of speech from a given tagset.

47. The system according to claim **44** wherein said parser takes as input one or more tagged documents (or the documents output by any other appropriate linguistic identification process) and outputs one or more parsed documents.

48. The system according to claim **41** wherein said conceptual annotator takes as input one or more linguistically annotated documents, a list of CSL Concepts and Concept Rules for annotation, and data from a synonym resource, and outputs one or more conceptually annotated documents.

49. The system according to claim **41** wherein said conceptually annotated documents are annotated with a representation in TML.

50. The system according to claim **41** wherein said input of one or more linguistically annotated documents to said conceptual annotator comes from the following sources:

a) the linguistic annotator directly;

b) storage in some linguistically annotated form such as the representation produced by the final linguistic identification process of the linguistic annotator;

c) storage in TML followed by conversion from TML to the representation produced by the final linguistic identification process of the linguistic annotator.

51. The system according to claim **41** wherein said conceptual annotator comprises a Concept identifier.

52. The system according to claim **51** wherein said Concept identifier produces conceptually annotated documents as a result of:

a) compiling CSL into finite state automata (FSAs);

b) matching said FSAs against linguistically annotated documents.

53. The system according to claim 52 wherein said compilation into FSAs also comprises as part of compilation one or both of the following:

a) the grammar from the parser used by the system to parse linguistically annotated documents; and

b) sets of synonyms.

54. The system according to claim 51 wherein said Concept identifier produces conceptually annotated documents as a result of recursive descent matching which consists of traversing an expression in CSL and recursively matching constituents of said expression against linguistic entities in linguistically annotated text.

55. The system according to claim 54 wherein said recursive descent matching comprises sets of synonyms.

56. The system according to claim 51 wherein said Concept identifier produces conceptually annotated documents as a result of bottom-up matching which comprises:

a) generating in a bottom-up fashion multiple spans, where each span is a word or constituent, or alternatively, a set of words and constituents that follow each other, plus some structural information about the word and constituent;

b) generating in a bottom-up fashion spans consumed by single-term patterns in an expression in CSL; .

c) generating in a bottom-up fashion spans consumed by operators in an expression in CSL; and.

d) matching in a bottom-up fashion said spans against linguistic entities in linguistically annotated documents.

57. The system according to claim **56** wherein said bottom-up matching comprises sets of synonyms.

58. The system according to claim **51** wherein said Concept identifier produces conceptually annotated documents as a result of methods for identifying Concepts that are index-based comprising use of an inverted index, where

a) said inverted index contains words, constituents, and tags for linguistic information from linguistically annotated text;
b) said inverted index contains spans for said words, constituents, and tags from linguistically annotated text;
c) where a span is a word or constituent, or alternatively, a set of words and constituents that follow each other, plus structural information about the word(s) and constituent(s).

59. The system according to claim **56** wherein said Concept identifier using index-based methods produces conceptually annotated documents as a result of index-based matching, where said index-based matching comprises:

a) using backtracking to resolve the constraints of CSL operators in an expression in CSL;
b) attaching iterators to all items in the CSL expression;
c) using the iterators to produce matches of all items in the CSL expression against text in the inverted index;
d) maintaining a state for the iterator for each item in the CSL expression where that state is used to determine whether or not it has been processed before in the match of said expression against said inverted index, and also relevant information about the progress of the match;
e) maintaining a state for the iterator for each item that is a word in the expression in CSL where that state

includes, but is not limited to, the following information: a list of applicable synonyms of the word in question, and the current synonym being used for matching; an iterator into the inverted index that can enumerate all instances of the word in said index, and which records the current word;

f) during the course of a match, each item in the CSL expression is tested, and if successful, returns a set of spans covering the match of its corresponding sub-expression.

60. The system according to claim **59** wherein said simple index-based matching comprises sets of synonyms.

61. The method according to claim **56** wherein said identification of concepts uses linguistic information, and said concepts are represented in a concept specification language, as a result of index-based methods for identifying concepts comprising candidate checking index-based matching where said candidate checking index-based matching comprises identifying sets of candidate spans, where

a) a candidate span is a span that might, but does not necessarily, contain a Concept to be identified;

b) any span that is not covered by a candidate span from the sets of candidate spans is one that cannot contain a Concept to be identified;

c) each sub-expression of a CSL Expression is associated with a procedure;

d) each such procedure is used to generate candidate spans or to check whether a given span is a candidate span.

62. The system according to claim **61** wherein said candidate spans produced by said candidate checking index-based matching serve as input to Concept identification methods comprises compiling and matching

finite state automata, recursive descent matching, bottom-up matching, and simple index based matching.

63. The system according to claim **56** wherein said Concept identifier produces conceptually annotated documents as a result of methods for identifying Concepts comprising using an inverted index with compiling and matching finite state automata, recursive descent matching, bottom-up matching, and simple index based matching.

64. The system according to claim **48** wherein said conceptually annotated documents are stored.

65. The system according to claim **20** wherein said CSL processor, accessed by said user interface, comprises a CSL Concept and Concept Rule learner, and a CSL query checker.

66. The system according to claim **65** wherein said CSL Concept and Concept Rule learner comprises:

a) highlighting instances of Concepts in the text of documents;

b) creating new CSL Rules from said highlighted instances of Concepts;

c) creating new CSL Concepts from said CSL Rules

d) adding and, if necessary, integrating said new CSL Concepts and Concept Rules with pre-existin g CSL Concepts and Concept Rules.

67. The system according to claim **66** wherein creating new CSL Rules comprises:

a) using the Concept identifier to match together CSL vocabulary specifications and highlighted linguistically annotated documents;

b) defining linguistic variants;

c) adding synonyms from a set of synonyms;

d) adding parts of speech.

68. The system according to claim **65** wherein said CSL Concept and Concept Rule learner comprises means for:

a) highlighting instances of Concepts in the text of linguistically annotated documents to produce highlighted linguistically annotated documents; where
b) said linguistically annotated documents can be either produced on demand or stored in TML or other formats; and
c) said highlighted linguistically annotated documents can be either produced on demand or stored in TML or other formats;
d) producing new CSL Concept Rules from said highlighted instances of Concepts in said highlighted linguistically annotated document; and
e) adding and, if necessary, integrating said new CSL Concepts and Concept Ru les with pre-existing CSL Concepts and Concept Rules.

69. The system according to claim **65** wherein said CSL Concept and Concept Rule learner comprises means for:

a) highlighting instances of Concepts in the text of documents to produce highlighted documents;
b) linguistic annotation of said documents to produce highlighted linguistically annotated documents;
c) said highlighted text documents can be either produced on demand or stored in TML or other formats;
d) said highlighted linguistically annotated documents can be either produced on demand or stored in TML or other formats;
e) producing new and CSL Concept Rules from said highlighted instances of Concepts in said highlighted linguistically annotated documents; and

f) adding and, if necessary, integrating said new CSL Concepts and Concept Rules with pre-existing CS L Concepts and Concept Rules.

70. The system according to claim **34** wherein said user-defined descriptions of CSL Concepts and Concept Rules comprise user queries to an information retrieval system, said user queries being represented in CSL.

71. The system according to claim **65** wherein said CSL query checker accessed by said user interface, takes as input a proposed CSL query and, if all queries are known in advance, passes said query to the retriever.

72. The system according to claim **65** wherein said CSL query checker accessed by said user interface, takes as input a proposed CSL query and, if all queries are not known in advance, matches said query against known CSL Concepts and Concept Rules and, if a match is found, then the query is parsed with a CSL parser and passed to the retriever.

73. The system according to claim **65** wherein said CSL query checker accessed by said user interface, takes as input a proposed CSL query and, if all queries are not known in advance, matches said query against known CSL Concepts and Concept Rules and, if a match is not found, then the query (a CSL expression) is parsed with a CSL parser and added to the list of CSL Concepts and Concept Rules to be annotated, which are then passed to the annotator.

74. The system according to claim **39** wherein said CSL parser takes as input a synonym database, CSL query, and CSL Concepts and Rules, and outputs CSL Concepts and Rules for annotation as a result of the following:

a) word compilation;

b) Concept compilation;

c) downward synonym propagation; and

d) upward synonym propagation.

75. The system according to claim **39** wherein said text document retriever accessed by said user interface, comprises a retriever which takes one or more annotated documents as input, passes retrieved and categorized documents to a TML converter, which passes them to a document viewer.

76. The method according to claim **34** wherein a tag hierarchy in the CSL is a set of declarations, each declaration relating a tag to a set of tags, declaring that each of the latter tags is to be considered an instance of the former tag.

77. The method according to claim **34** wherein a Concept in the CSL is used to represent concepts.

78. The method according to claim **77** wherein a Concept in the CSL can either be global or internal to other Concepts.

79. The method according to claim **77** wherein a Concept in the CSL uses words and other Concepts in the definition of Concept Rules.

80. The method according to claim **79** wherein a Concept Rule in the CSL comprises an optional name internal to the Concept followed by a Pattern.

81. The method according to claim **80** wherein a Pattern in the CSL may match:

a) single terms in an annotated text; or

b) some configuration in an annotated text.

82. The method according to claim **81** wherein a single-term Pattern in the CSL may comprise a reference to:

a) the name of a word, and optionally;

b) its part of speech tag; and

c) synonyms of the word.

83. The method according to claim **81** wherein a configurational Pattern in the CSL may consist of the form *A* Operator *B*, where the Operator is Boolean.

84. The method according to claim **81** wherein a configuration in the CSL is any expression in the notation used to represent syntactic descriptions.

85. The method according to claim **84** wherein a configurational Pattern in the CSL may consist of the form *A* Operator *B*, where the Operator is of two types:

a) Dominance, and

b) Precedence.

86. The method according to claim **84** wherein a configurational Pattern in the CSL according to claim **85** may consist of the form *A* Dominates *B*, where

a) *A* is a syntactic constituent;

b) *B* is any Pattern.

87. The method according to claim **86** wherein a configurational Pattern in the CSL of the form *A* Dominates *B* may be wide-matched, where said wide-matching returns the interval of *A* in a text is returned instead of *B*; and where said interval is a consecutive sequence of words in a text that is represented as two integers separated by a dash.

88. The method according to claim **87** wherein a configurational Pattern in the CSL consists of the form *A* Precedes *B*, where

a) *A* is any Pattern;

b) *B* is any Pattern.

89. The method according to claim **83** wherein a Boolean operator in the CSL can be applied to any Patterns to obtain further Patterns.

90. The method according to claim **81** wherein any of the Patterns thus defined in the CSL is a CSL Expression.

91. The method according to claim **81** wherein a Pattern thus defined in the CSL is fully recursive.

92. The method according to claim **81** wherein a Macro in the CSL represents a Pattern in a compact, parameterized form and can be used wherever a Pattern is used.

93. The method according to claim **34** wherein said concepts, represented in said CSL or any other concept specification language derive from the sublanguages used by experts to analyze event-based specialized domains comprising insurance claims, police incident reports, medical reports, and aviation incident reports.

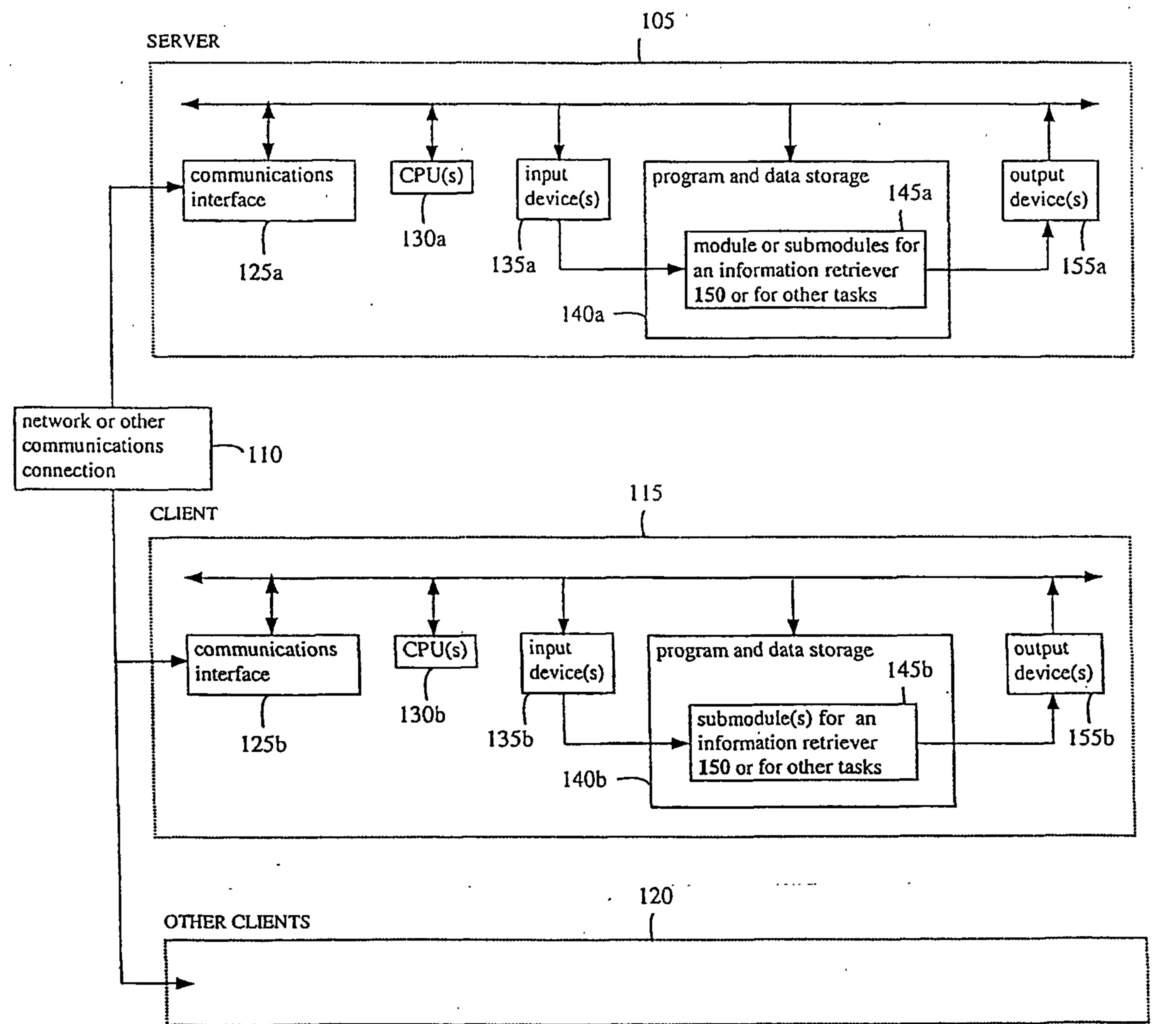

105
SERVER
communications interface
CPU(s)
input device(s)
program and data storage
145a
output device(s)
module or submodules for an information retriever 150 or for other tasks
125a
130a
135a
155a
140a
network or other communications connection
110
115
CLIENT
communications interface
CPU(s)
input device(s)
program and data storage
145b
output device(s)
submodule(s) for an information retriever 150 or for other tasks
125b
130b
135b
155b
140b
120
OTHER CLIENTS

FIG. 1

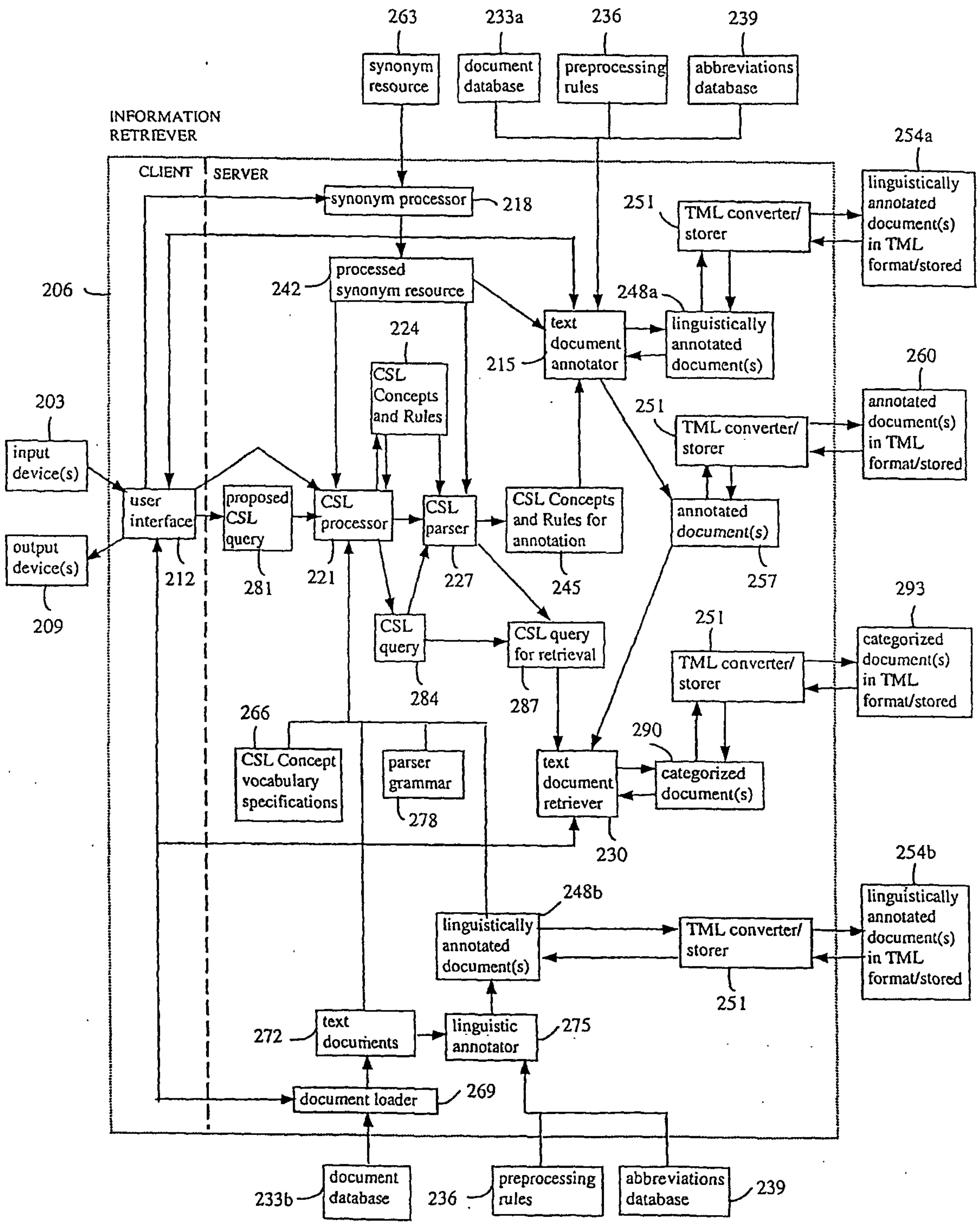


FIG. 2.

SUBSTITUTE SHEET

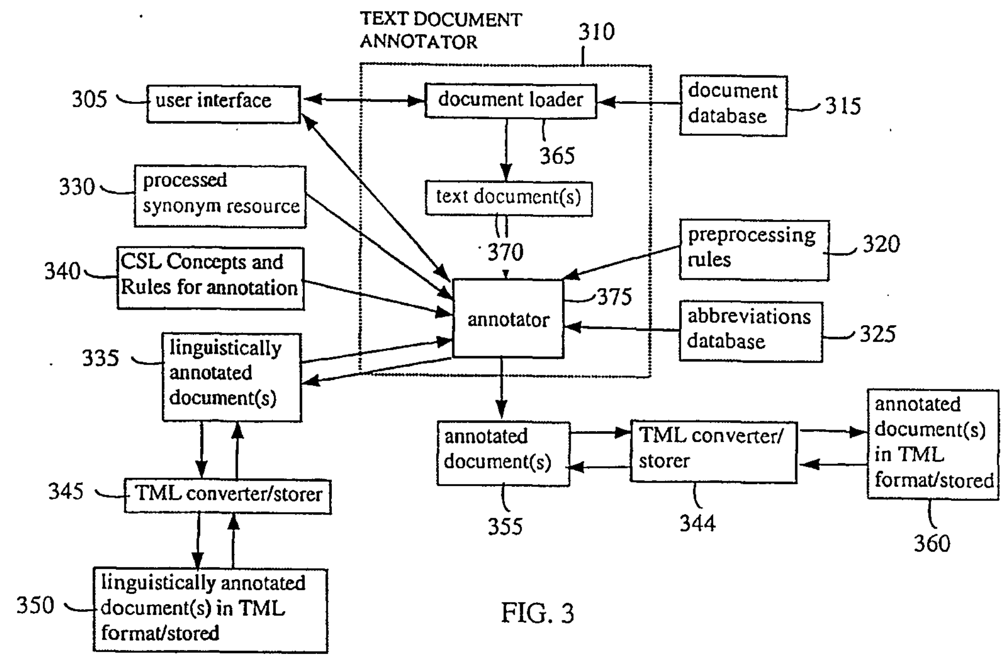

TEXT DOCUMENT ANNOTATOR
310
305
user interface
document loader
document database
315
365
330
processed synonym resource
text document(s)
370
preprocessing rules
320
340
CSL Concepts and Rules for annotation
annotator
375
abbreviations database
325
335
linguistically annotated document(s)
annotated document(s)
TML converter/ storer
annotated document(s) in TML format/stored
345
TML converter/storer
355
344
360
350
linguistically annotated document(s) in TML format/stored

FIG. 3

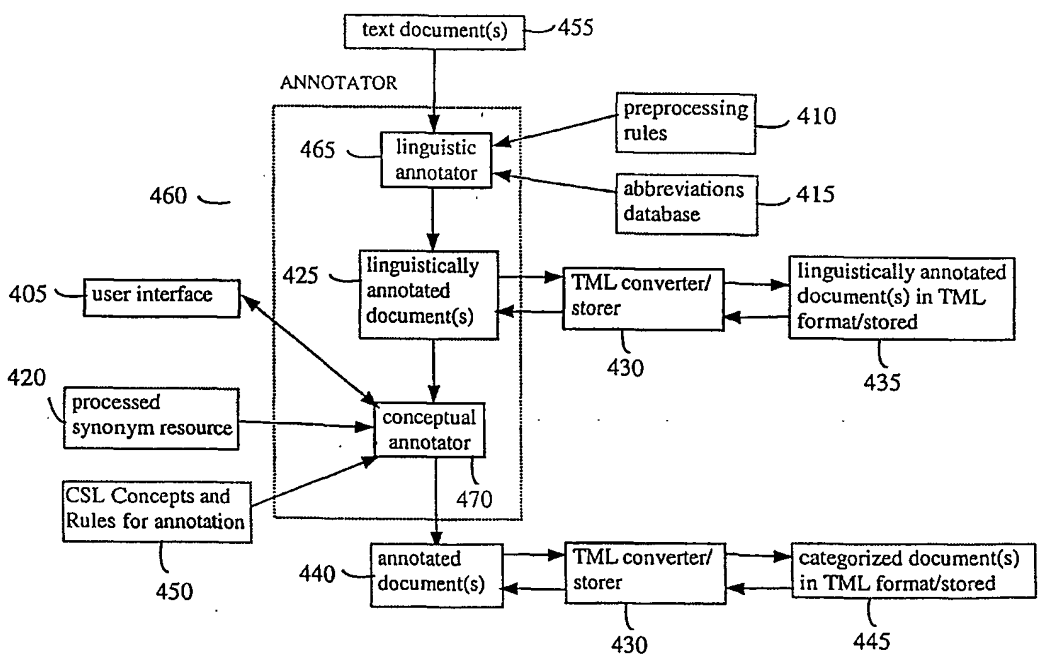
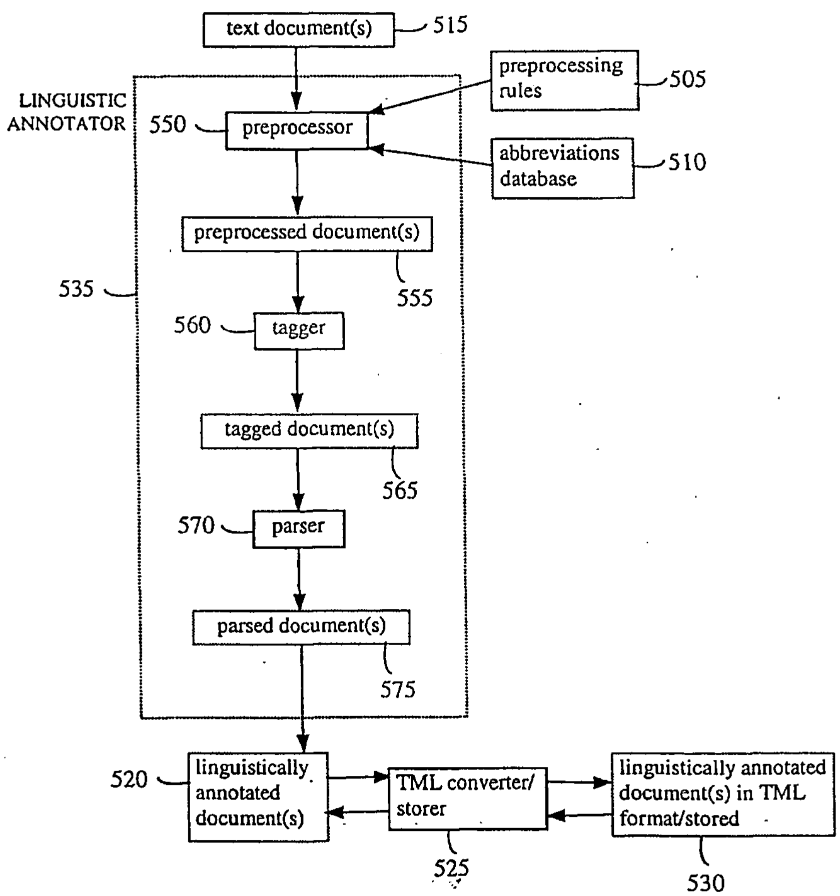

text document(s)
455
ANNOTATOR
preprocessing rules
410
465
linguistic annotator
460
abbreviations database
415
425
linguistically annotated document(s)
TML converter/ storer
linguistically annotated document(s) in TML format/stored
405
user interface
430
435
420
processed synonym resource
conceptual annotator
CSL Concepts and Rules for annotation
470
440
annotated document(s)
TML converter/ storer
categorized document(s) in TML format/stored
450
430
445

FIG. 4



text document(s)
515
preprocessing rules
505
LINGUISTIC ANNOTATOR
550
preprocessor
abbreviations database
510
preprocessed document(s)
535
555
560
tagger
tagged document(s)
565
570
parser
parsed document(s)
575
520
linguistically annotated document(s)
TML converter/ storer
linguistically annotated document(s) in TML format/stored
525
530

FIG. 5

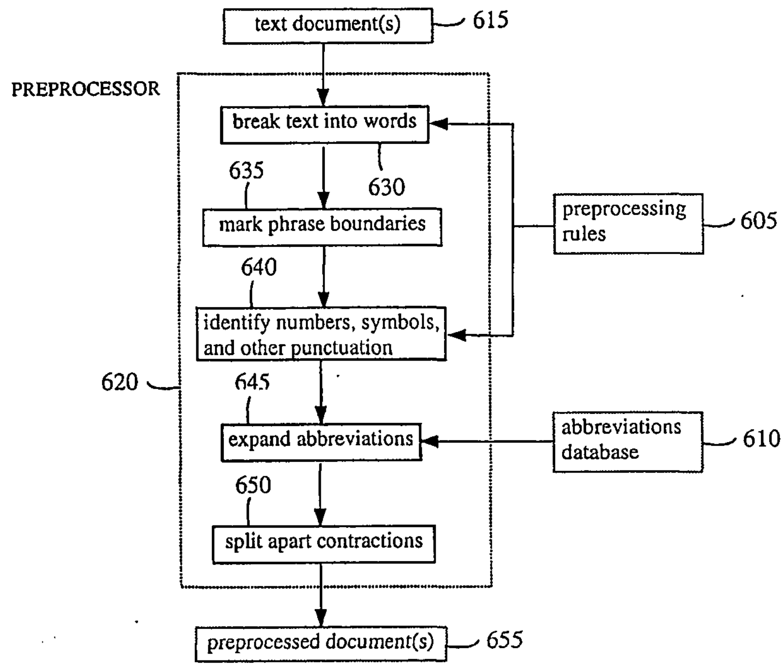

text document(s)
615
PREPROCESSOR
break text into words
635
630
mark phrase boundaries
preprocessing rules
605
640
identify numbers, symbols, and other punctuation
620
645
expand abbreviations
abbreviations database
610
650
split apart contractions
preprocessed document(s)
655

FIG. 6

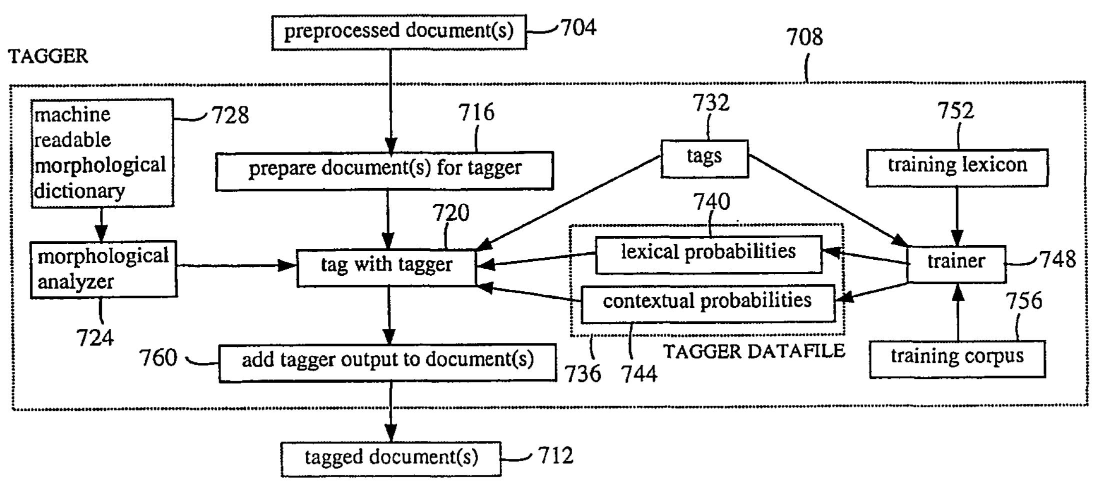

preprocessed document(s)
704
708
TAGGER
machine readable morphological dictionary
728
716
732
752
prepare document(s) for tagger
tags
training lexicon
720
740
morphological analyzer
tag with tagger
lexical probabilities
trainer
748
contextual probabilities
756
724
760
add tagger output to document(s)
736
744
TAGGER DATAFILE
training corpus
tagged document(s)
712

FIG. 7

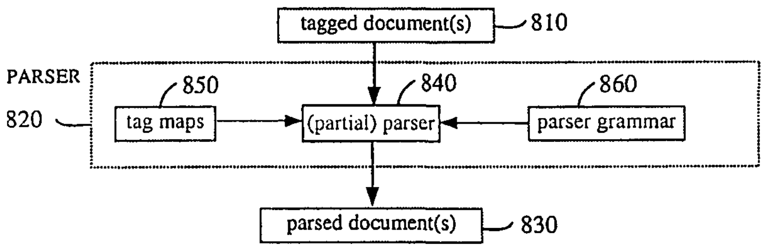

tagged document(s)
810
PARSER
820
850
tag maps
840
(partial) parser
860
parser grammar
parsed document(s)
830

FIG. 8

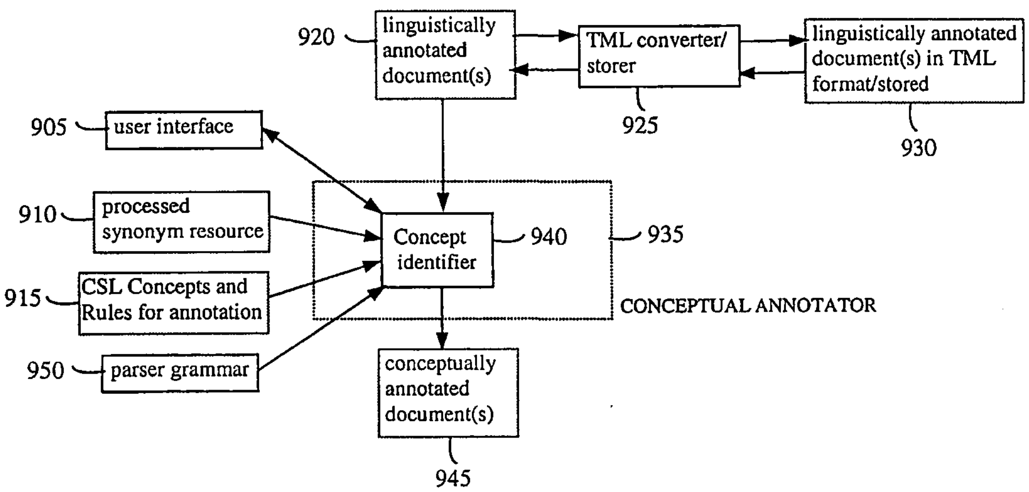

920
linguistically annotated document(s)
TML converter/ storer
linguistically annotated document(s) in TML format/stored
925
930
905
user interface
910
processed synonym resource
915
CSL Concepts and Rules for annotation
950
parser grammar
Concept identifier
940
935
CONCEPTUAL ANNOTATOR
conceptually annotated document(s)
945

FIG. 9

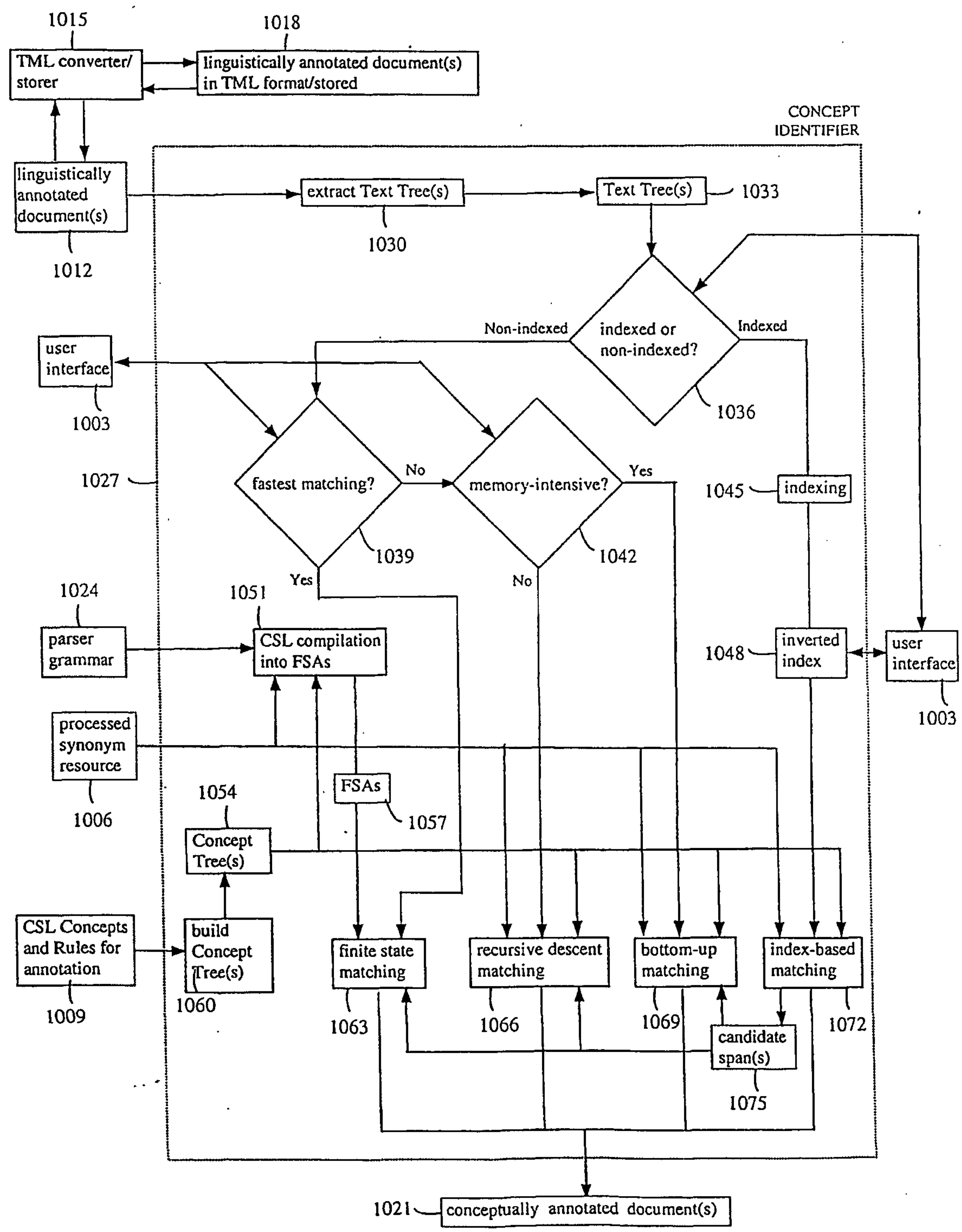

1015
TML converter/ storer
1018
linguistically annotated document(s) in TML format/stored
CONCEPT IDENTIFIER
linguistically annotated document(s)
1012
extract Text Tree(s)
1030
Text Tree(s)
1033
indexed or non-indexed?
Non-indexed
Indexed
1036
user interface
1003
fastest matching?
No
memory-intensive?
Yes
1027
1039
1042
Yes
No
1045
indexing
1024
parser grammar
1051
CSL compilation into FSAs
1048
inverted index
user interface
1003
processed synonym resource
1006
1054
FSAs
1057
Concept Tree(s)
CSL Concepts and Rules for annotation
1009
build Concept Tree(s)
1060
finite state matching
1063
recursive descent matching
1066
bottom-up matching
1069
index-based matching
1072
candidate span(s)
1075
1021
conceptually annotated document(s)

FIG. 10

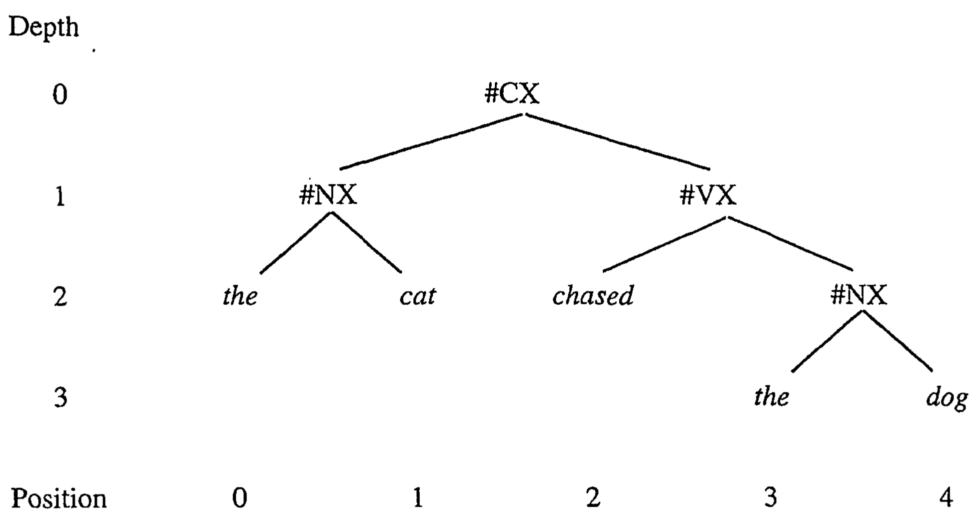


FIG. 11

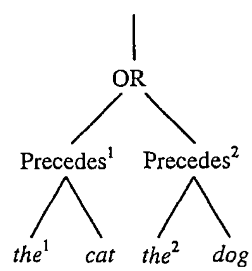


FIG. 12

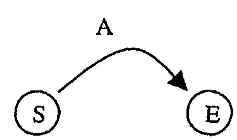


FIG. 13

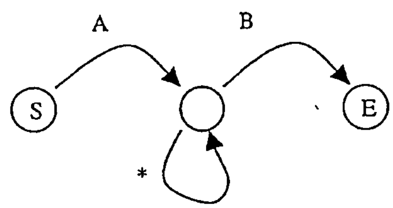


FIG. 14

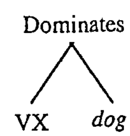


FIG. 15

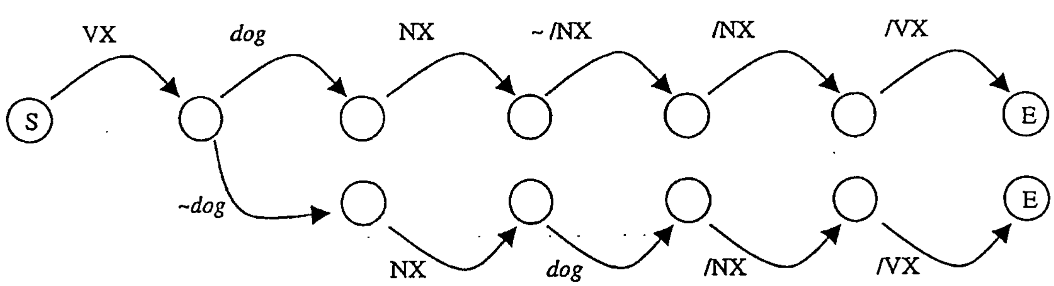


FIG. 16

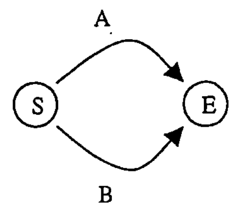


FIG. 17

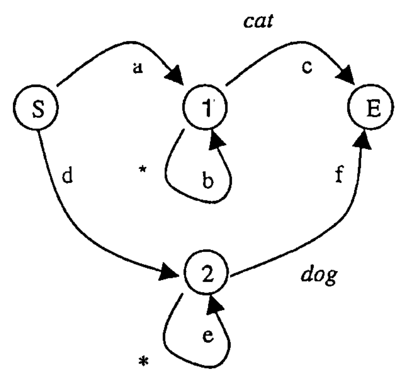


FIG. 18

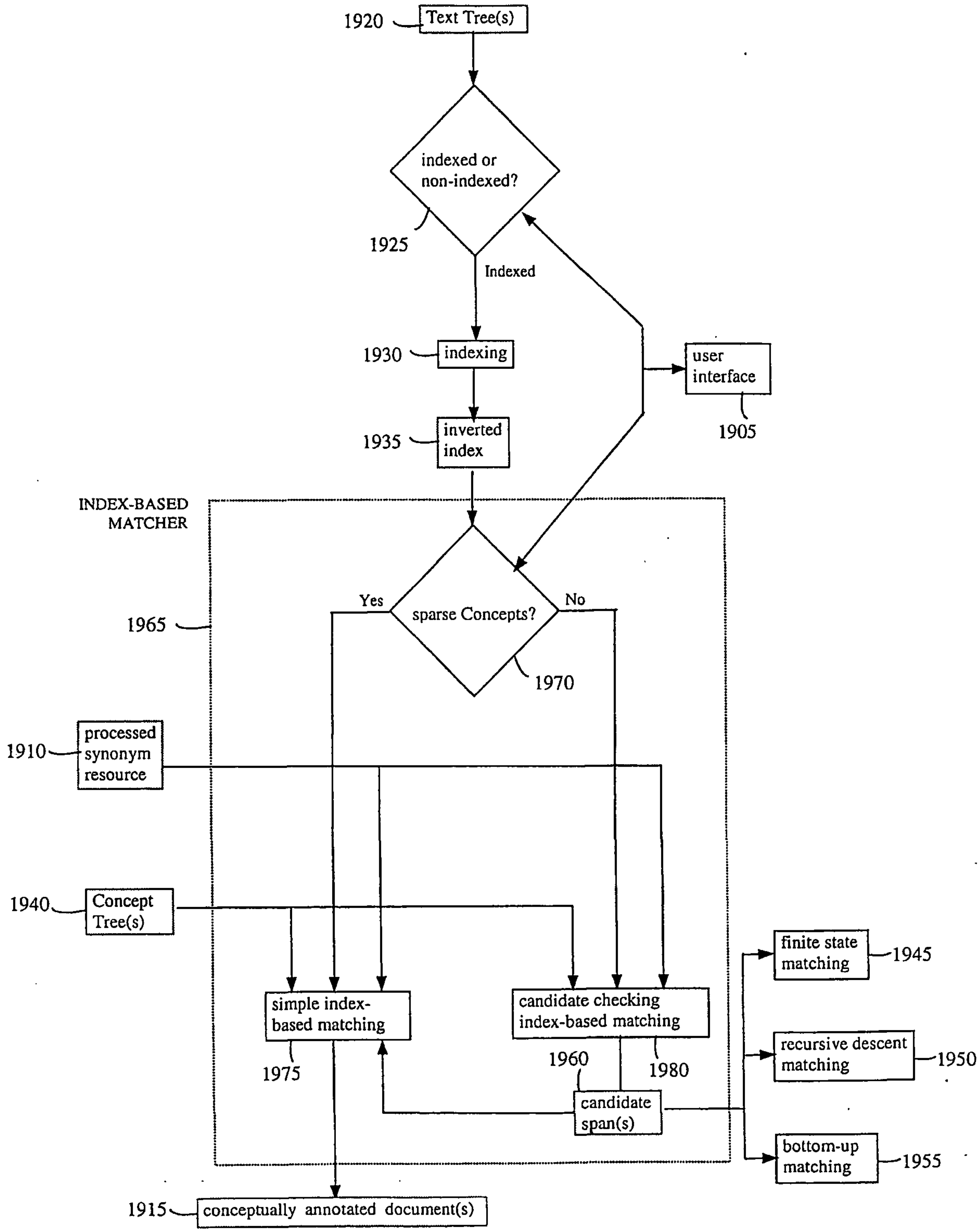

1920
Text Tree(s)
indexed or non-indexed?
1925
Indexed
1930
indexing
1935
inverted index
user interface
1905
INDEX-BASED MATCHER
1965
Yes
sparse Concepts?
No
1970
1910
processed synonym resource
1940
Concept Tree(s)
finite state matching
1945
simple index-based matching
candidate checking index-based matching
recursive descent matching
1950
1975
1960
1980
candidate span(s)
bottom-up matching
1955
1915
conceptually annotated document(s)

FIG. 19

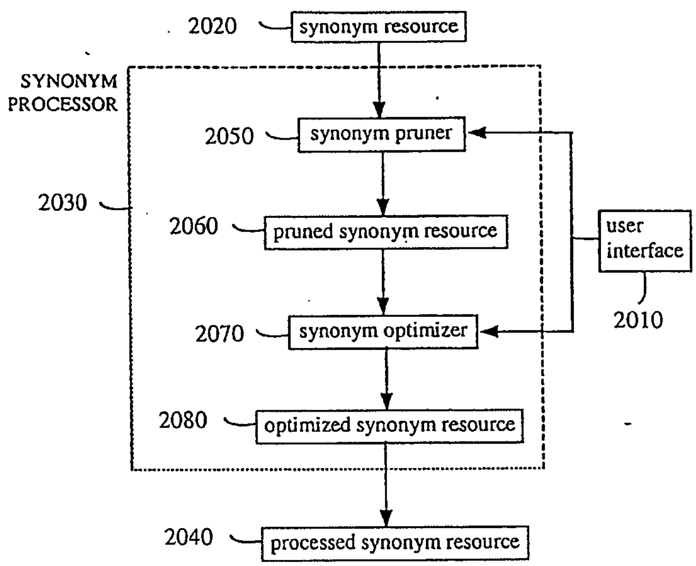


FIG. 20

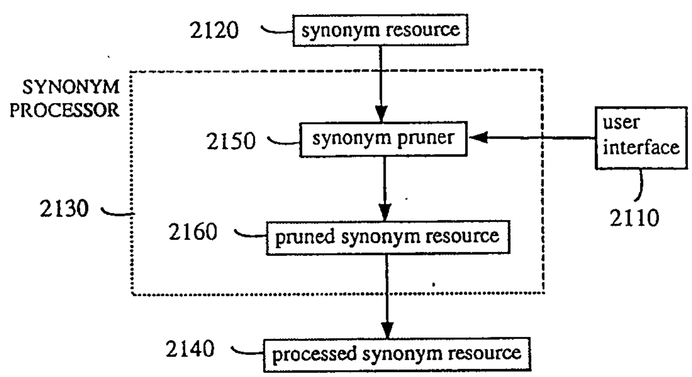


FIG. 21

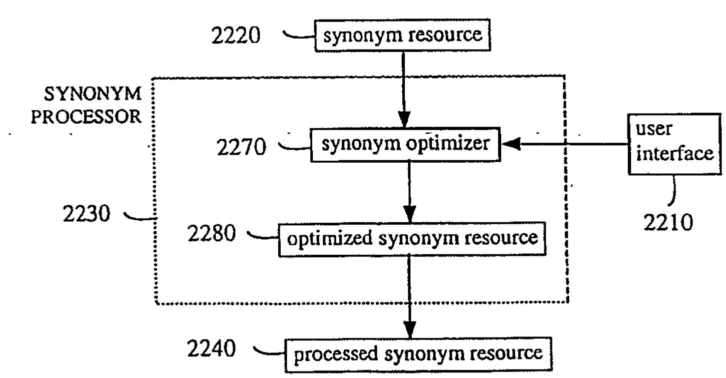


FIG. 22

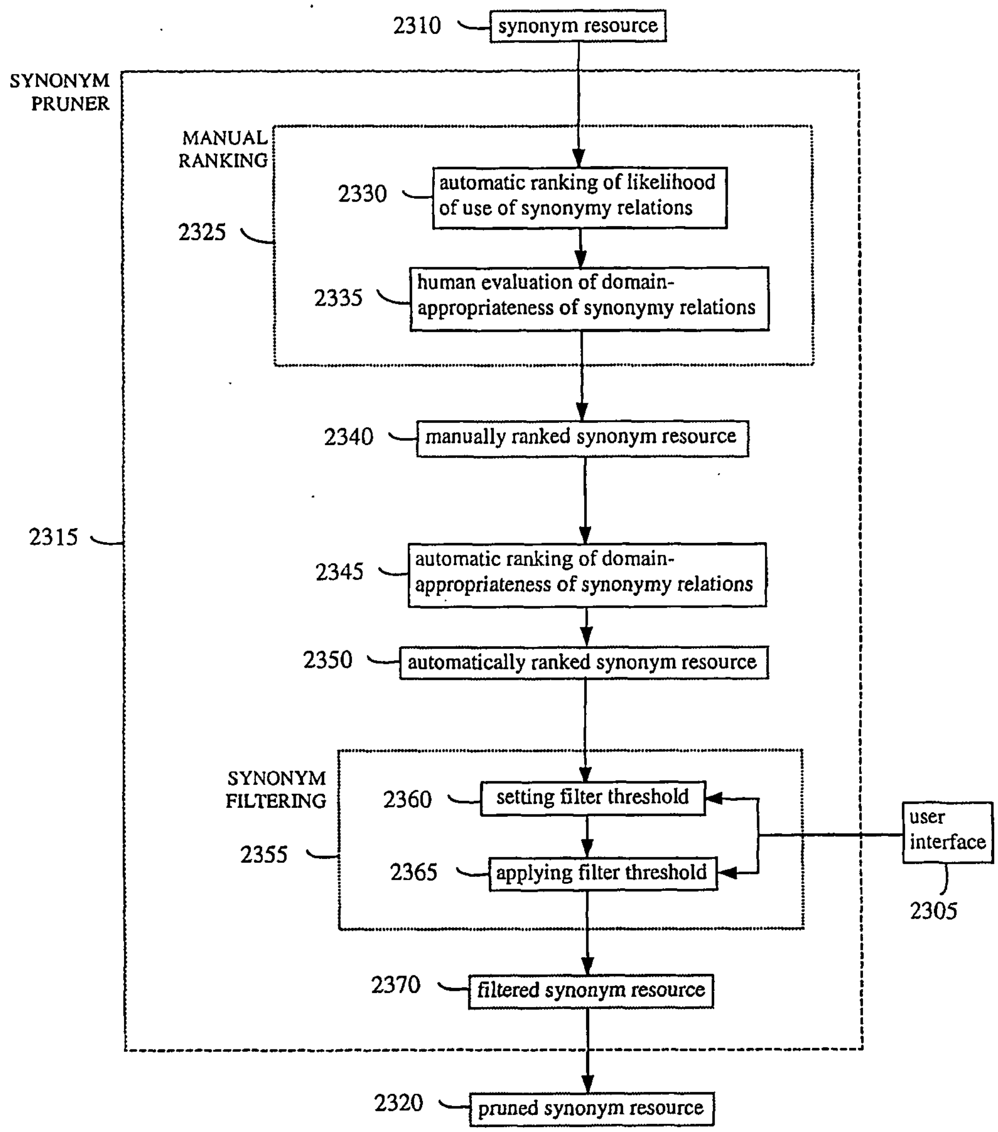

2310
synonym resource
SYNONYM PRUNER
MANUAL RANKING
2330
automatic ranking of likelihood of use of synonymy relations
2325
2335
human evaluation of domain-appropriateness of synonymy relations
2340
manually ranked synonym resource
2315
2345
automatic ranking of domain-appropriateness of synonymy relations
2350
automatically ranked synonym resource
SYNONYM FILTERING
2360
setting filter threshold
user interface
2355
2365
applying filter threshold
2305
2370
filtered synonym resource
2320
pruned synonym resource

FIG. 23

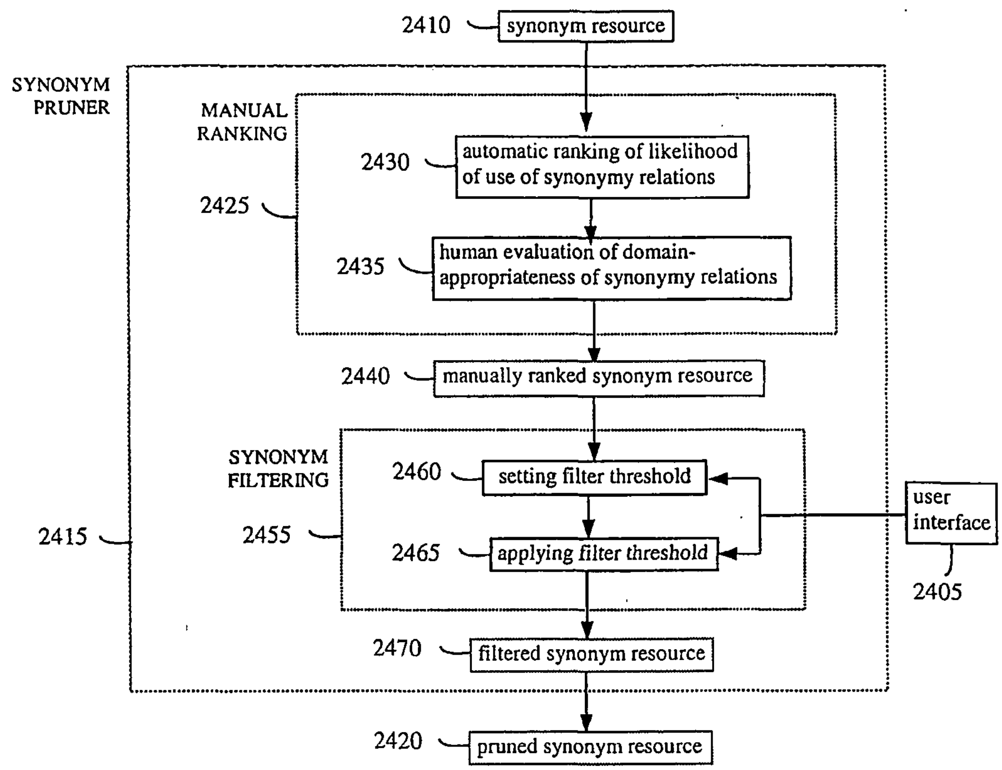

2410
synonym resource
SYNONYM PRUNER
MANUAL RANKING
2430
automatic ranking of likelihood of use of synonymy relations
2425
2435
human evaluation of domain-appropriateness of synonymy relations
2440
manually ranked synonym resource
SYNONYM FILTERING
2460
setting filter threshold
2415
2455
2465
applying filter threshold
user interface
2405
2470
filtered synonym resource
2420
pruned synonym resource

FIG. 24

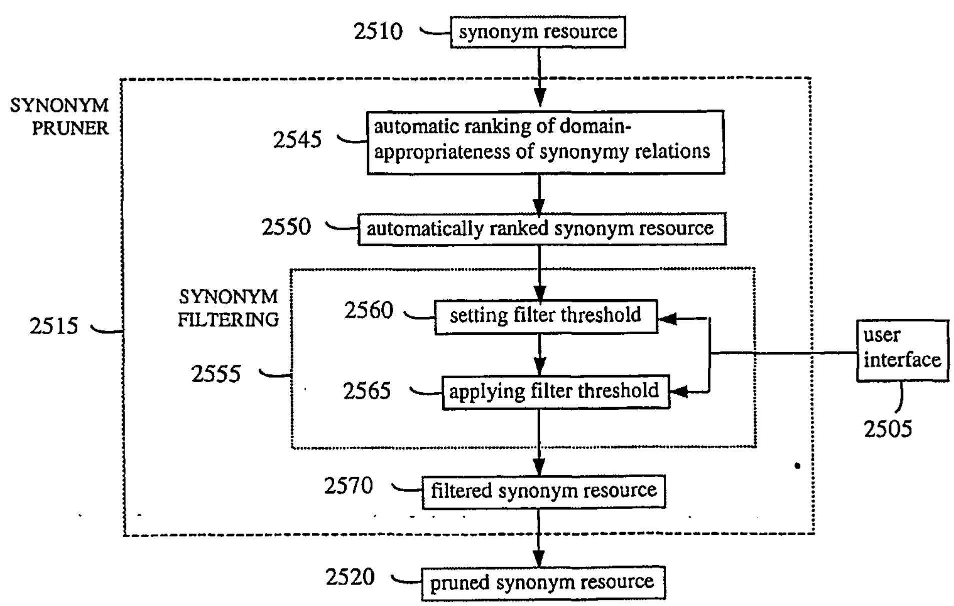
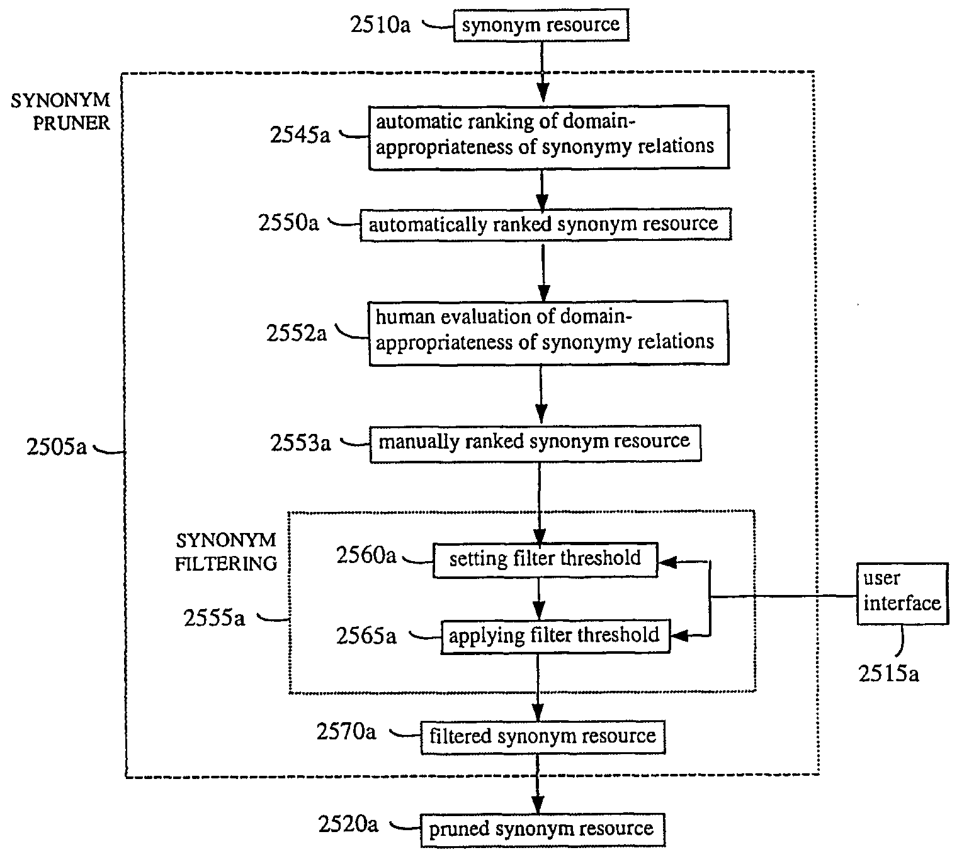

2510
synonym resource
SYNONYM PRUNER
2545
automatic ranking of domain-appropriateness of synonymy relations
2550
automatically ranked synonym resource
SYNONYM FILTERING
2560
setting filter threshold
2515
2555
2565
applying filter threshold
user interface
2505
2570
filtered synonym resource
2520
pruned synonym resource

FIG. 25



2510a
synonym resource
SYNONYM PRUNER
2545a
automatic ranking of domain-appropriateness of synonymy relations
2550a
automatically ranked synonym resource
2552a
human evaluation of domain-appropriateness of synonymy relations
2505a
2553a
manually ranked synonym resource
SYNONYM FILTERING
2560a
setting filter threshold
2555a
2565a
applying filter threshold
user interface
2515a
2570a
filtered synonym resource
2520a
pruned synonym resource

FIG. 25a

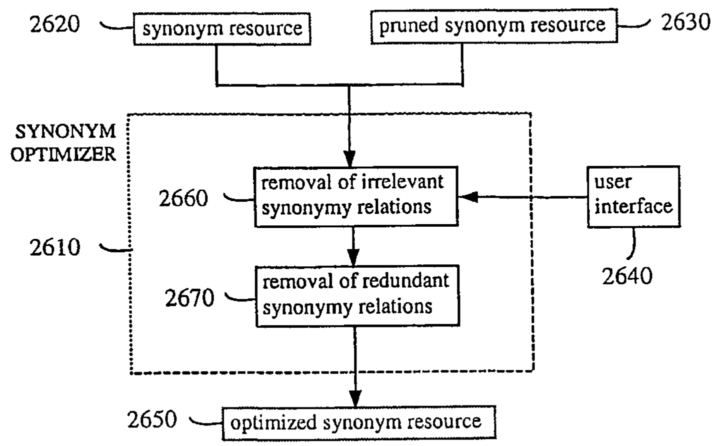


FIG. 26

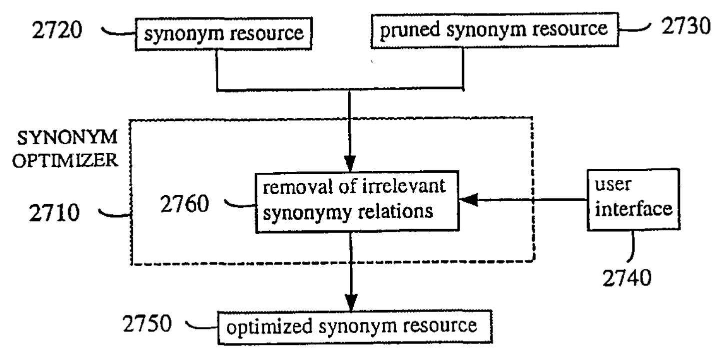


FIG. 27

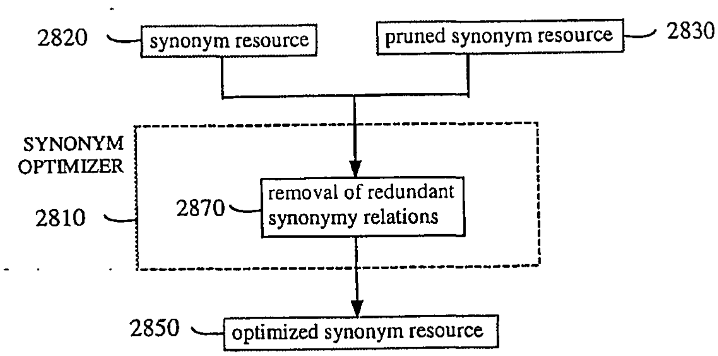


FIG. 28

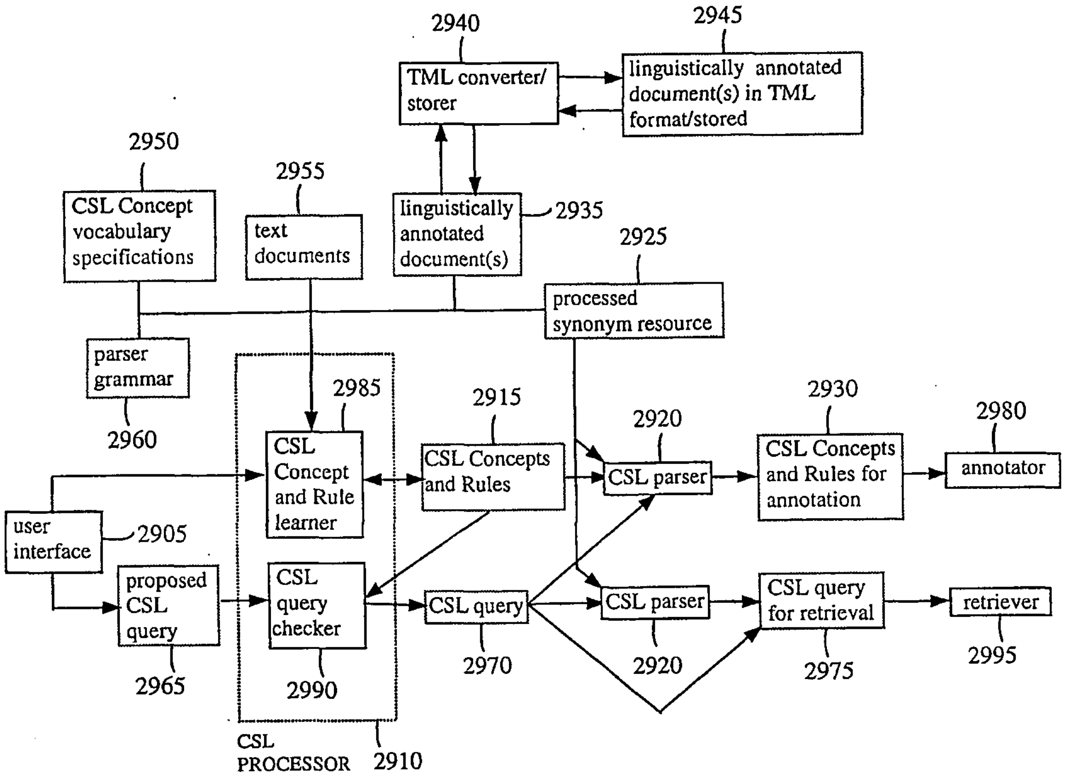
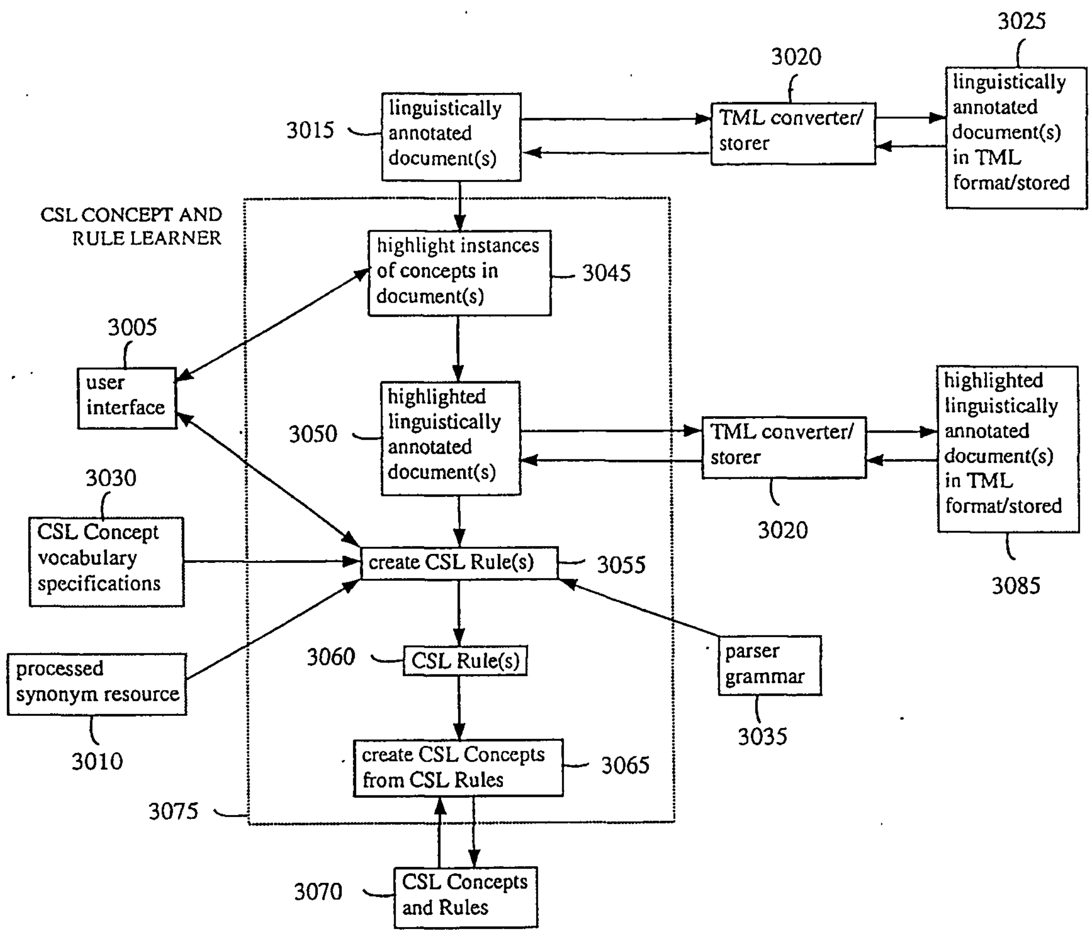
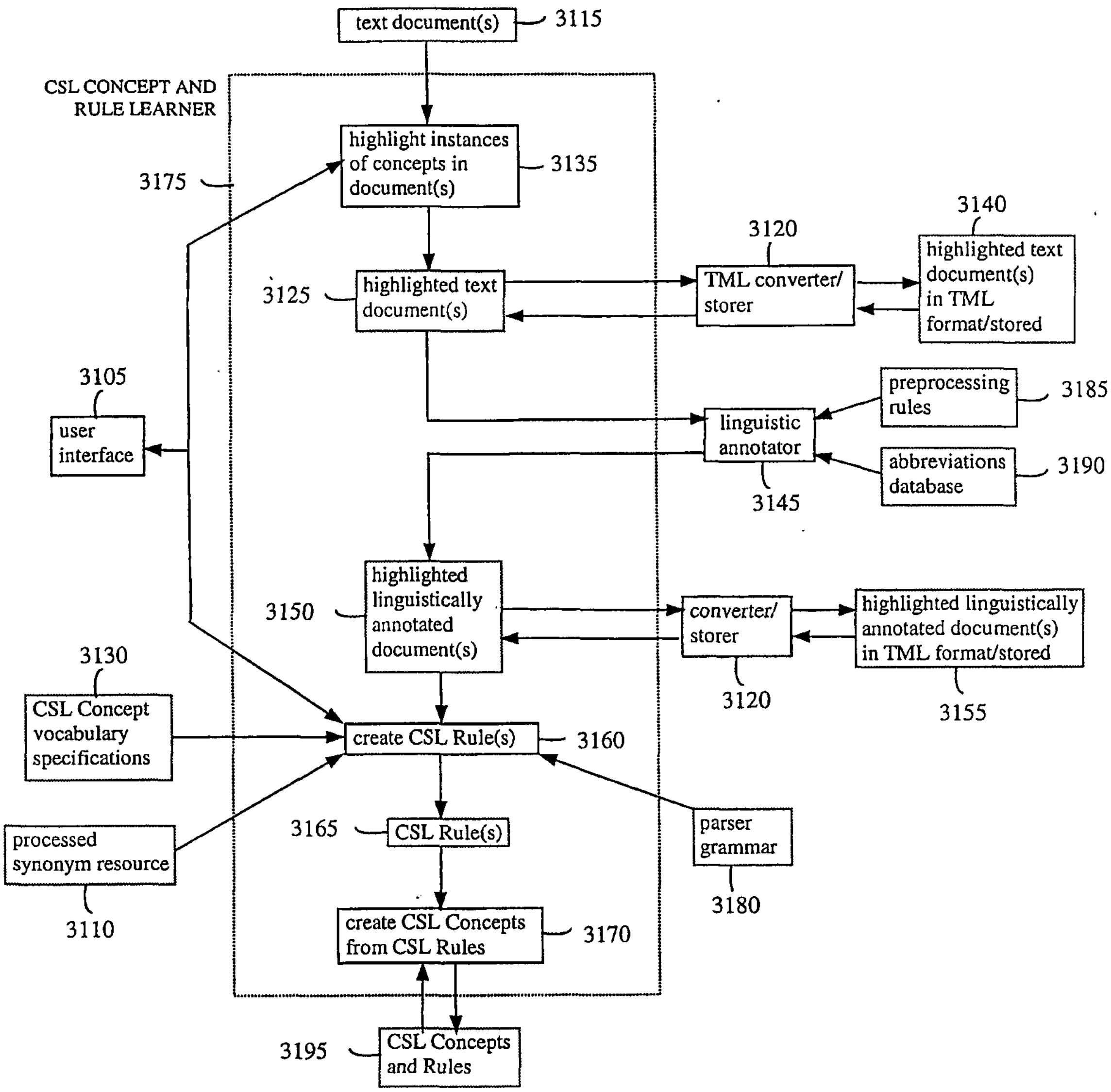

2940
TML converter/ storer
2945
linguistically annotated document(s) in TML format/stored
2950
CSL Concept vocabulary specifications
2955
text documents
linguistically annotated document(s)
2935
2925
processed synonym resource
parser grammar
2960
2985
CSL Concept and Rule learner
2915
CSL Concepts and Rules
2920
CSL parser
2930
CSL Concepts and Rules for annotation
2980
annotator
user interface
2905
proposed CSL query
2965
CSL query checker
2990
CSL query
2970
CSL parser
2920
CSL query for retrieval
2975
retriever
2995
CSL PROCESSOR
2910

FIG. 29



3025
3020
linguistically annotated document(s)
3015
TML converter/ storer
linguistically annotated document(s) in TML format/stored
CSL CONCEPT AND RULE LEARNER
highlight instances of concepts in document(s)
3045
3005
user interface
highlighted linguistically annotated document(s)
3050
TML converter/ storer
highlighted linguistically annotated document(s) in TML format/stored
3030
CSL Concept vocabulary specifications
3020
create CSL Rule(s)
3055
3085
3060
CSL Rule(s)
parser grammar
processed synonym resource
3035
3010
create CSL Concepts from CSL Rules
3065
3075
3070
CSL Concepts and Rules

FIG. 30



text document(s)
3115
CSL CONCEPT AND RULE LEARNER
highlight instances of concepts in document(s)
3135
3175
3140
3120
highlighted text document(s)
3125
TML converter/ storer
highlighted text document(s) in TML format/stored
3105
user interface
preprocessing rules
3185
linguistic annotator
abbreviations database
3190
3145
highlighted linguistically annotated document(s)
3150
converter/ storer
highlighted linguistically annotated document(s) in TML format/stored
3130
3120
3155
CSL Concept vocabulary specifications
create CSL Rule(s)
3160
processed synonym resource
3165
CSL Rule(s)
parser grammar
3110
3180
create CSL Concepts from CSL Rules
3170
3195
CSL Concepts and Rules

FIG. 31

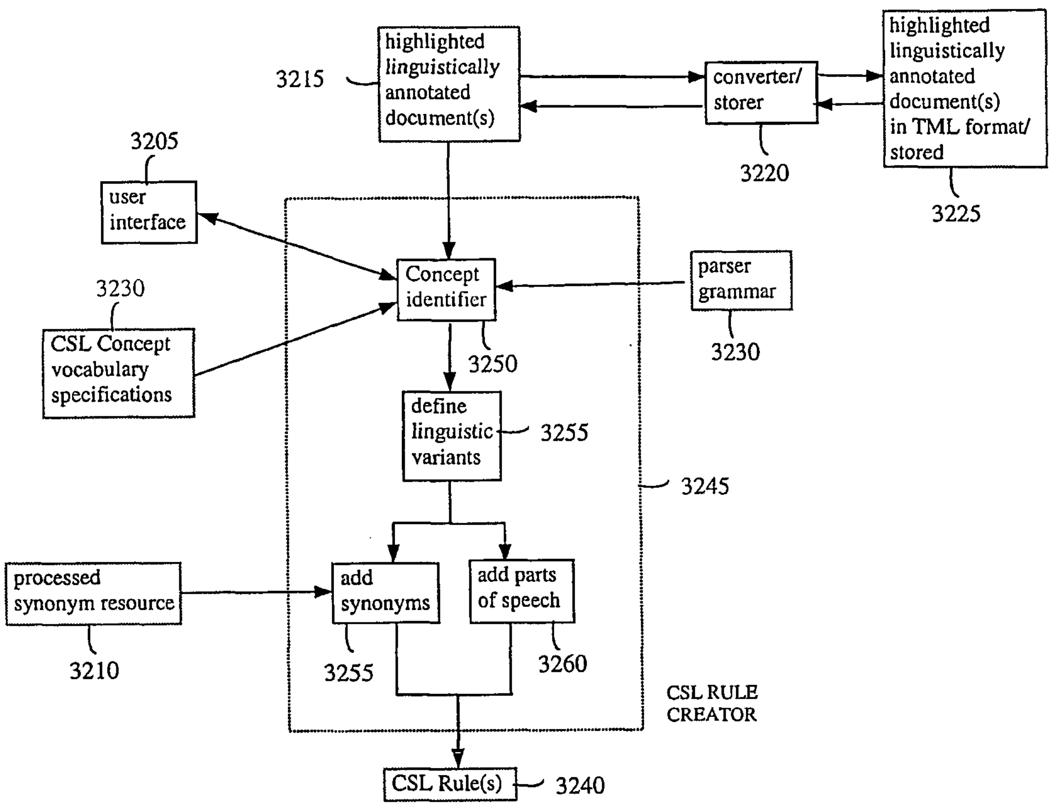

highlighted linguistically annotated document(s)
3215
converter/ storer
3220
highlighted linguistically annotated document(s) in TML format/ stored
3225
3205
user interface
3230
CSL Concept vocabulary specifications
Concept identifier
3250
parser grammar
3230
define linguistic variants
3255
3245
processed synonym resource
3210
add synonyms
3255
add parts of speech
3260
CSL RULE CREATOR
CSL Rule(s)
3240

FIG. 32

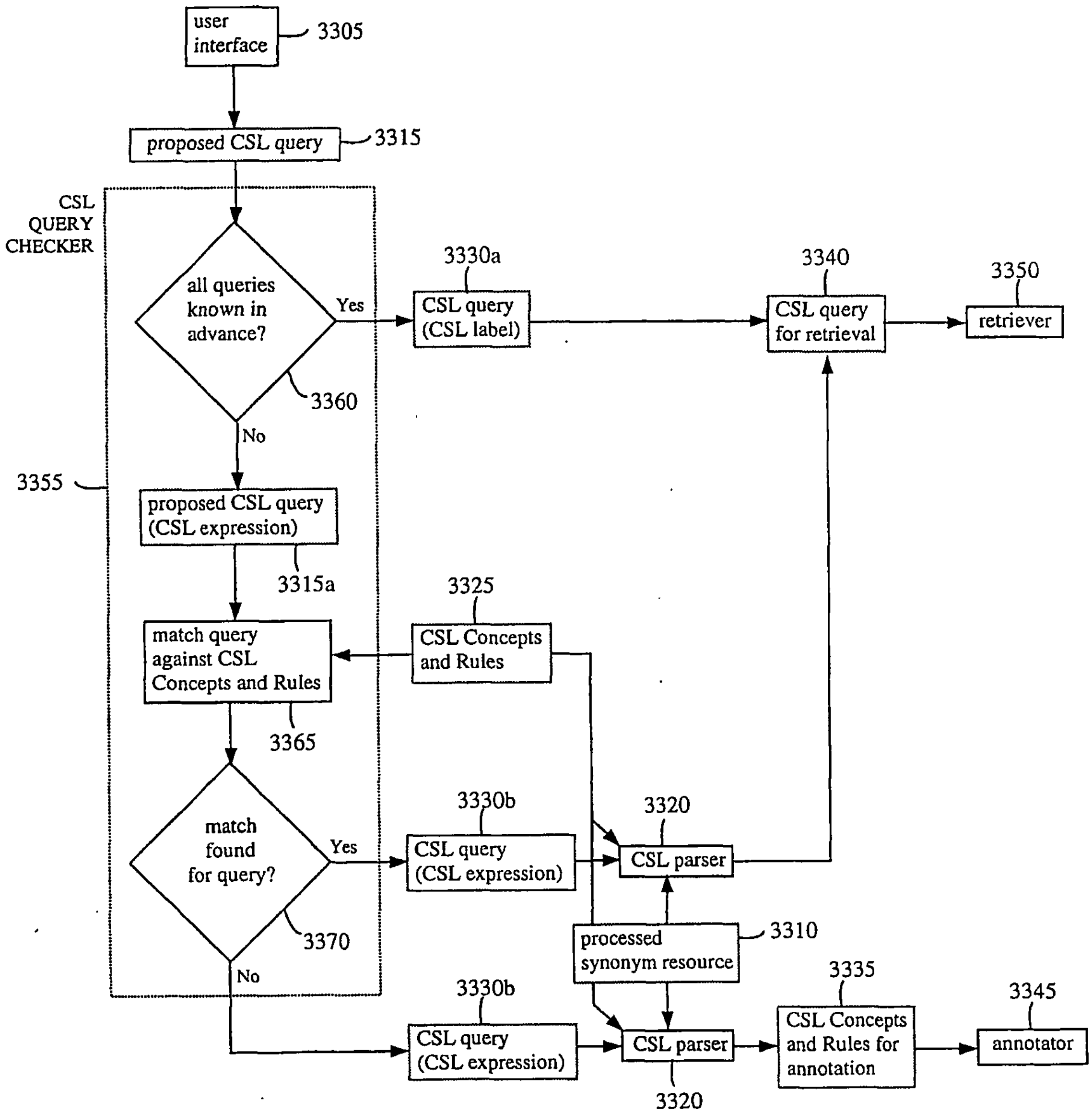

user interface
3305
proposed CSL query
3315
CSL QUERY CHECKER
all queries known in advance?
Yes
No
3360
3330a
CSL query (CSL label)
3340
CSL query for retrieval
3350
retriever
3355
proposed CSL query (CSL expression)
3315a
3325
CSL Concepts and Rules
match query against CSL Concepts and Rules
3365
3330b
3320
match found for query?
Yes
No
CSL query (CSL expression)
CSL parser
3370
processed synonym resource
3310
3335
3345
3330b
CSL query (CSL expression)
CSL parser
CSL Concepts and Rules for annotation
annotator
3320

FIG. 33

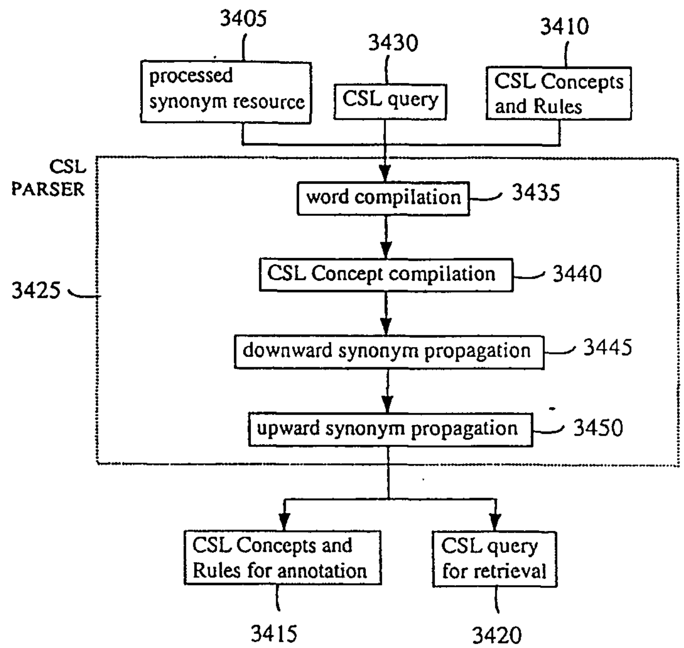

3405
processed synonym resource
3430
CSL query
3410
CSL Concepts and Rules
CSL PARSER
3425
word compilation
3435
CSL Concept compilation
3440
downward synonym propagation
3445
upward synonym propagation
3450
CSL Concepts and Rules for annotation
CSL query for retrieval
3415
3420

FIG. 34

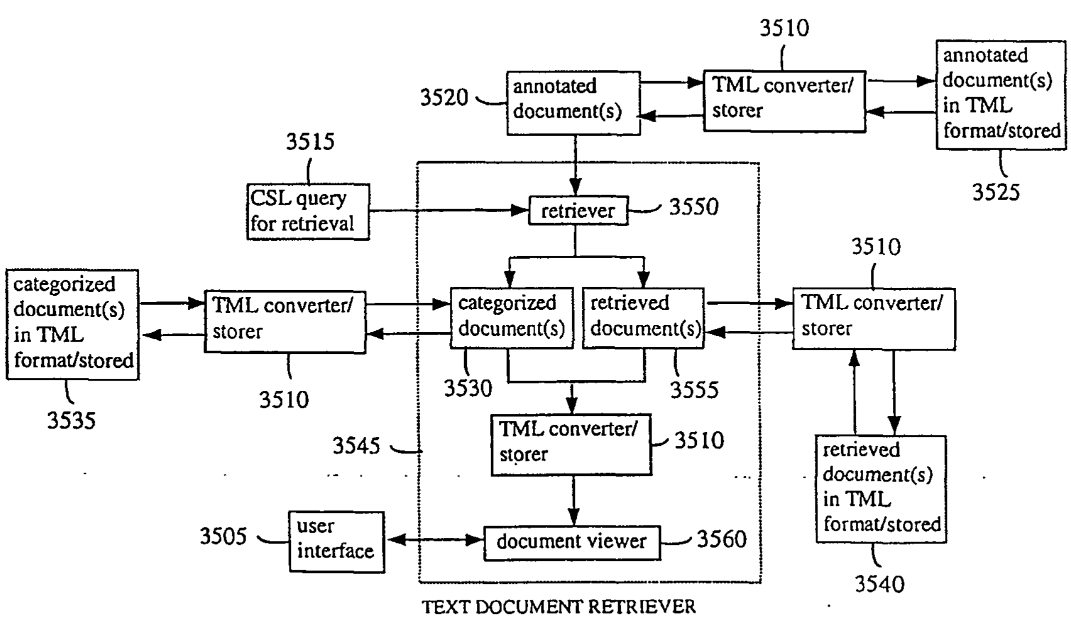

3510
3520
annotated document(s)
TML converter/ storer
annotated document(s) in TML format/stored
3525
3515
CSL query for retrieval
retriever
3550
3510
categorized document(s) in TML format/stored
TML converter/ storer
categorized document(s)
retrieved document(s)
TML converter/ storer
3535
3510
3530
3555
3545
TML converter/ storer
3510
retrieved document(s) in TML format/stored
3505
user interface
document viewer
3560
3540
TEXT DOCUMENT RETRIEVER

FIG. 35